e-Weather Observers' Handbook

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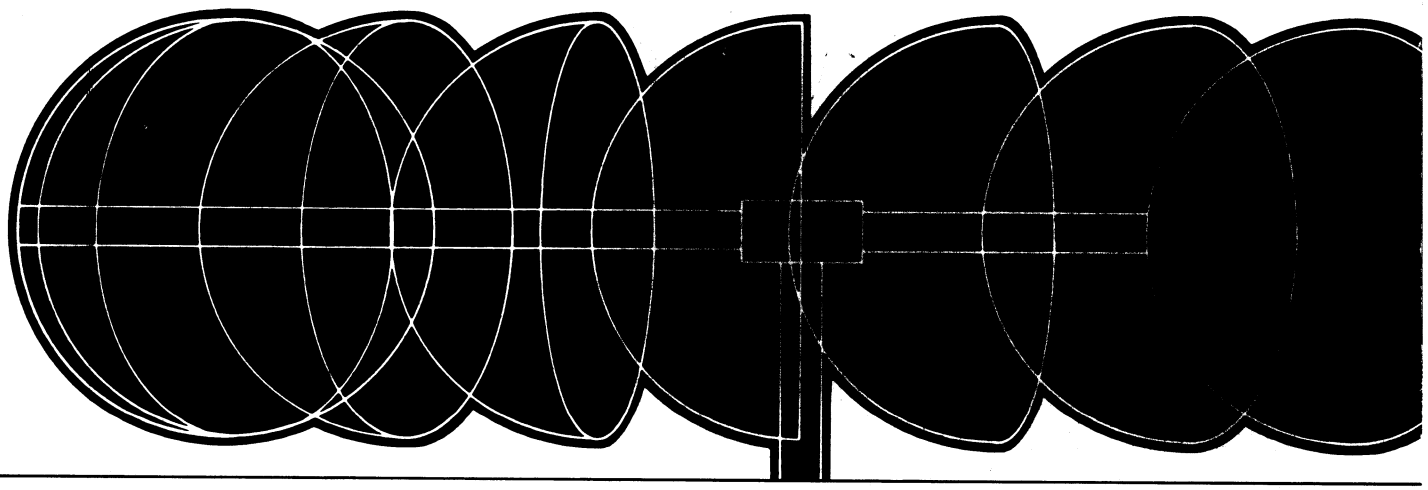

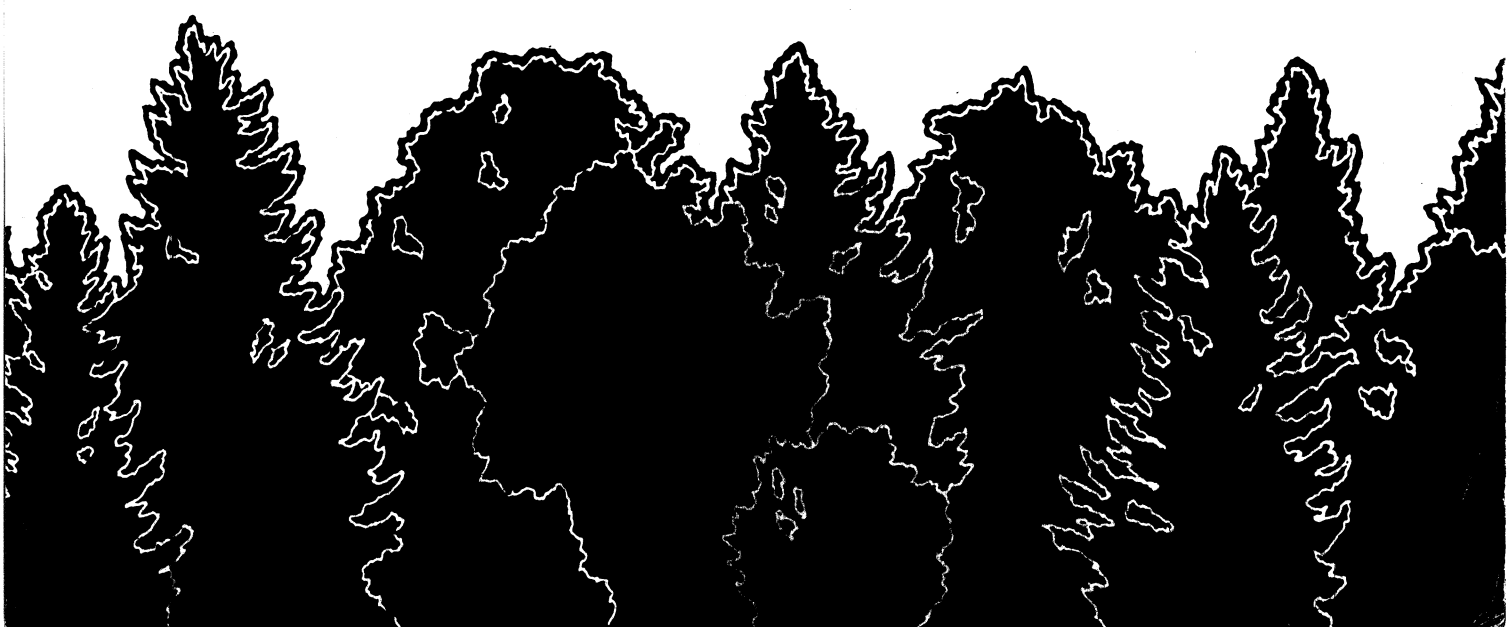

FIRE-WEATHER OBSERVERS' HANDBOOK

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Agriculture Handbook No. 494

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Fire-weather measurements of interest are noted and the instruments used are described. Specifications for the location and layout of a fire-weather station are given along with installation instructions for suggested equipment. Step-by-step instrument operating and maintenance instructions are provided. Emphasis is on minimizing the major sources of error commonly associated with weather measurement. (Formerly issued by the Intermountain Forest and Range Experiment Station, USDA Forest Service, Ogden, Utah, under the same title in May 1972).

CONTENTS

INTRODUCTION

As its title implies, this handbook will serve as an important tool for the fire-weather observer. It is equally intended, however, to serve the needs of fire managers who are responsible for the collection of fire-weather data and the installation and maintenance of fire-weather stations or networks of stations. In addition, certain portions of the handbook have been expanded beyond strictly fire-weather needs to increase its usefulness as a general reference for land managers and forestry researchers.

OBJECTIVE

The overall objective of the handbook is to improve both the reliability and comparability of data collected at fire-weather stations. To accomplish this, the handbook offers uniform standards and procedures designed to avoid, or at least minimize, the major sources of error commonly associated with weather measurement. These sources of error have been identified as: (1) instrumental error; (2) observational error; (3) exposure error; and (4) sampling error (Smith 1970).

The standards and procedures provided to deal with the above sources of error are consistent with well-established practices of meteorological organizations and fire control agencies. Publications of the National Weather Service (United States); Meteorological Division, Department of Transport (Canada); World Meteorological Organization (United Nations); USDA Forest Service; and Canada Department of Forestry were major sources for the development of the recommended standards.

HANDBOOK ORGANIZATION

A simple recipe is proposed for avoiding, or at least minimizing, the previously mentioned sources of error associated with weather measurement. The four basic ingredients of this recipe provide the organizational framework for this handbook.

The first ingredient is a **knowledge of the instruments and how they work.** This is important in eliminating or minimizing all four sources of weather measurement error. Part 1 of this handbook provides this knowledge by briefly defining the various fire-weather measurements of concern and describing the instruments used to obtain these measurements.

Proper installation and exposure of the instruments within a properly located station is the second major ingredient for reliable weather measurements. Adherence to standards for the location, arrangement, installation, and exposure of weather instruments is essential if sampling and exposure error are to be avoided. Part 2 of the handbook provides the required standards for proper location and layout of fire-weather stations as well as installation and exposure standards for the recommended instruments.

The third ingredient requires **adherence to correct instrument operating instructions** in

order to minimize observational error. Part 3 of the handbook provides step-by-step operating instructions for the more common fire-weather instruments.

The final ingredient in our recipe for minimizing error in weather measurement is **an adequate program of continuous instrument and station maintenance.** This is a major factor in guarding against instrument error. Part 4 of the handbook therefore contains detailed maintenance instructions for the fire-weather instruments discussed in the preceding three parts of the handbook.

Cross Reference System

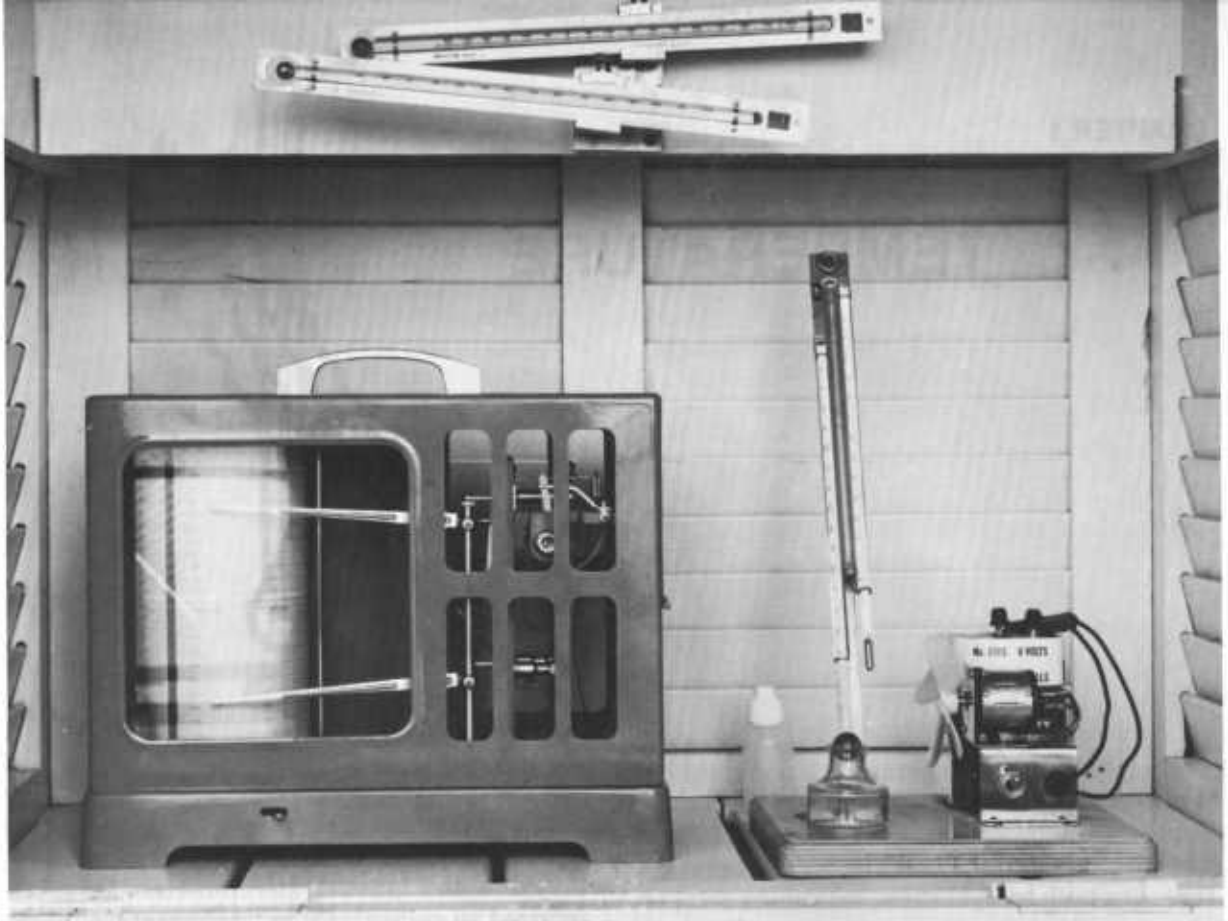
The organizational framework described above is, in the authors' judgment, a suitable way to arrange the subject matter to accomplish the previously stated objective of this handbook. The authors recognize, however, that this type of functional organization can create difficulties in using the handbook in reference to any one instrument. To facilitate this type of use, a system of cross referencing is provided following each functional discussion of a particular weather instrument. By using the cross reference, the reader can quickly locate additional information on the instrument of interest in the other three sections of the handbook.

FIRE-DANGER RATING

Traditionally, a close relationship has been recognized between fire-weather observation and fire-danger rating. Keetch (1966), in his plea for quality control in fire-danger rating, finds it imperative to establish and maintain uniform standards of weather measurement in order to use fire-danger ratings with confidence. More recently, Pirsko and Scowcraft (1969) have demonstrated how fire-danger indices computed from inaccurate fire-weather readings can result in erroneous presuppression manning actions.

Because of this close relationship between fire-weather observation and fire-danger rating, the past literature on observation practices and station standards consisted, almost exclusively, of regional fire-danger rating handbooks. Since the general adaption of the Spread Phase of the National Fire-Danger Rating System in the United States, these regional fire-danger rating handbooks have gradually gone out of print.

At present, the only generally available source of fire-weather observation information and station standards in the United States is the National Fire-Danger Rating System Handbook (USDA Forest Service 1964b), a part of the Forest Service directive system. Fire people in California have the Wildland Fire-Danger Rating System Handbook (USDA Forest Service 1962). Both of these sources will become obsolete when the completed National Fire-Danger Rating System (Deeming and Lancaster 1971) is generally adopted nationwide in 1972 or 1973. Fire-weather observation procedures and station standards required for operation of the completed National Fire-Danger Rating System can be provided by this edition of the Fire-Weather Observers Handbook.



PART 1.
FIRE-WEATHER MEASUREMENTS

A fire-weather observer will be better equipped to obtain consistently accurate weather data if he understands something about what he is attempting to measure and what his measurements represent. It is equally important that he understands his instruments, how they operate to provide the desired measurements, and the level of accuracy and reliability that can be expected from them.

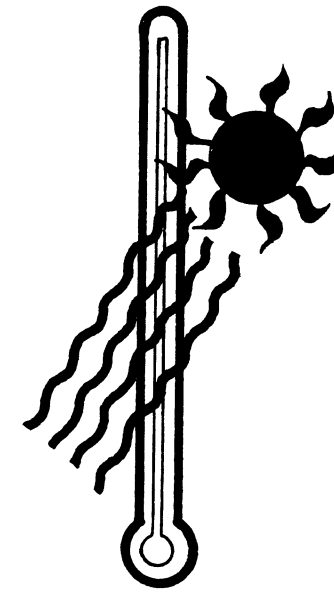
A detailed description of the various weather elements routinely measured at fire-weather stations is beyond the scope of this handbook. Fire-weather observers are encouraged to study the excellent treatment of this subject in the Fire Weather Handbook provided by Schroeder and Buck (1970). In the pages that follow, the fire-weather elements of interest are simply defined and the necessary measurements are explained.

Most of the text in this part of the handbook is devoted to weather instruments and how they work. If the fire manager understands how the various instruments work, he is more likely to install and expose them properly. By the same token, the observer who knows his instruments is better equipped to read them correctly, and maintain them adequately. The observer should be able to recognize a faulty reading and correct either it or the instrument immediately. In addition, the observer who knows what makes his instrument "tick" will more readily detect defects and recognize malfunctions.

An observer who truly understands what he is measuring and how his instruments operate will be more likely to collect usable data; furthermore, he may experience a high degree of satisfaction in doing what might otherwise be a bothersome, mechanical task.

CHAPTER 1

TEMPERATURE



Simply stated, temperature is a measure of the degree of hotness or coldness of the air. Temperature measurements routinely taken at fire-weather stations are: wet-bulb temperature; dry-bulb temperature; maximum temperature; and minimum temperature. Dry-bulb temperature at observation time is also the current temperature.

Wet- and dry-bulb temperature measurements are taken primarily to calculate relative humidity and dewpoint and are discussed in chapter 2 which deals with these subjects.

Maximum and minimum temperatures are the highest and lowest temperatures occurring during any period of time. For fire-weather purposes, this usually is the 24-hour period preceding the scheduled afternoon observation time. Maximum and minimum temperatures can be used to obtain an average temperature for the period of time they represent.

1.1 INSTRUMENTS

For fire-weather purposes, thermometers calibrated in degrees Fahrenheit (°F.) are used and temperatures are measured near the ground.

These thermometers are of several types, differing both in design and in operating principle. At fire-weather stations, liquid-in-glass thermometers, Bourdon thermometers, and bimetal thermometers are commonly used.

Bourdon and Bimetal Thermometers

Since they are designed to change form with corresponding changes in temperature, Bourdon and bimetal thermometers are often referred to collectively as "deformation" thermometers. Deformation thermometers are used as temperature sensing elements in dial thermometers and hygrothermographs and are discussed in section 2.3.

Liquid-in-Glass Thermometers

Liquid-in-glass thermometers indicate temperature by the difference in expansion between the liquid (mercury or alcohol) and the glass bore in which the liquid is enclosed. The bulb at the bottom of the glass bore acts as a reservoir for the liquid which rises and falls as temperature increases and decreases.

Mercury-filled thermometers are designed to measure temperatures above -38° F. (the freezing point of mercury); alcohol- or spirit-filled thermometers are designed to measure extremely low temperatures.

Liquid-in-glass thermometers vary in length of stem and shape of bulb. As a general rule, long-stemmed thermometers can be read more precisely than those with short stems. Everything else being equal, a thermometer having a cylindrical bulb will indicate changes in air temperature faster (i.e., will have less lag time) than one equipped with a round bulb (fig. 1.1).

LIQUID – IN – GLASS THERMOMETERS

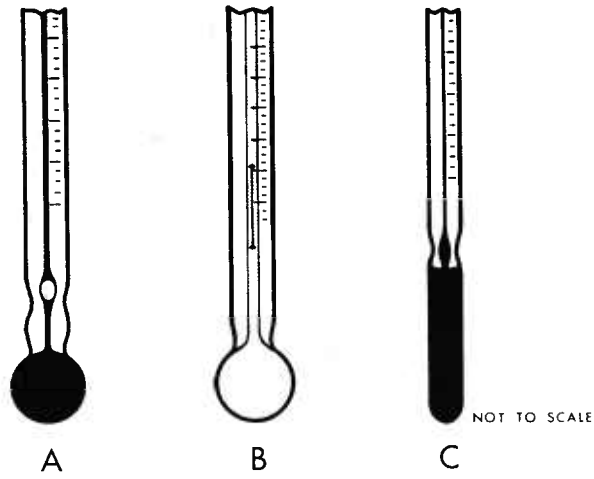


Figure 1.1. — Liquid-in-glass thermometers: *A*, Mercury-filled maximum thermometer; *B*, alcohol-filled minimum thermometer; *C*, standard dry-bulb mercury thermometer.

Figure 1.2. — Standard maximum-minimum thermometers mounted in a Townsend Support. The maximum thermometer is in the lower or spinning bracket. The minimum thermometer is in the upper bracket.

Standard Maximum-Minimum Thermometer

The standard maximum-minimum thermometer (actually two thermometers) consists of a mercury and a spirit thermometer fixed in a special mounting device called a Townsend Support or spinning bracket (fig. 1.2). When properly exposed in a suitable instrument shelter, they become a very accurate means for measuring maximum and minimum temperatures. This instrument is recommended for use at all permanent fire-weather stations.

The maximum thermometer is mercury-filled and has a small constriction in the capillary (the fine bore of the tube) just above the bulb (fig. 1.1). As the mercury in the bulb expands with increasing temperature, some of it is forced past this constriction. When the temperature drops, the mercury above the constriction will not retreat into the bulb; hence, when the bulb end of the thermometer is lowered to a reading position, the top of the column indicates the highest temperature attained.

After being read, the thermometer is reset by whirling in its mount. This forces the mercury through the constriction and back into the bulb.

The mimimum thermometer is alcohol-filled and has a small glass index rod, shaped like a dumbbell, floating in the bore (fig. 1.1). This index can move freely in the alcohol. When the temperature drops, the alcohol contracts and retreats down the bore. As the alcohol column contracts, it drags the index with it by means of surface tension at the top of the column. When the temperature again rises, the alcohol flows past the index, leaving it at the lowest temperature attained.

The thermometer is reset by turning it upside down in its mount until the index returns to the "top" of the alcohol column.

The Townsend Support facilitates reading and setting the maximum and minimum thermometers. The Support is designed for mounting on the cross board inside an instrument shelter.

CROSS REFERENCE: Installation and Exposure 8.2; Operation 10.1-10.3; Maintenance 16.1-16.4.

Combined Maximum-Minimum Thermometer

The Six's, or combined maximum-minimum thermometer, is a U-shaped, spirit (creosote) thermometer that has a mercury column as an indicator. A metal index rod, or dumbbell, rests at the top of the mercury column on each side of the tube (fig. 1.3). This index rod is pushed up the tube when the mercury column rises. The rod is left behind when the column falls.

The scale along the left side of the U-shaped tube is reversed; hence, the top of either mercury column always indicates current temperature. The scale along the right side of the tube indicates maximum temperature and the scale on the left indicates minimum temperature. Readings for maximum and minimum temperatures are obtained at the lower edge of the appropriate index rod.

After each observation, the instrument is reset by using a small magnet to draw the metal index rods down to the top of the mercury columns.

Combined maximum-minimum thermometers are not as sensitive as the standard thermometers previously described; however, they may be useful where a high degree of accuracy is not required. The following procedures are essential to proper operation of this instrument: periodic checking against a standard thermometer; proper maintenance; exposure in constant shade and free-moving air (preferably in a suitable instrument shelter).

CROSS REFERENCE: Operation 10.1-10.2, 10.4; Maintenance 16.1-16.3, 16.5.

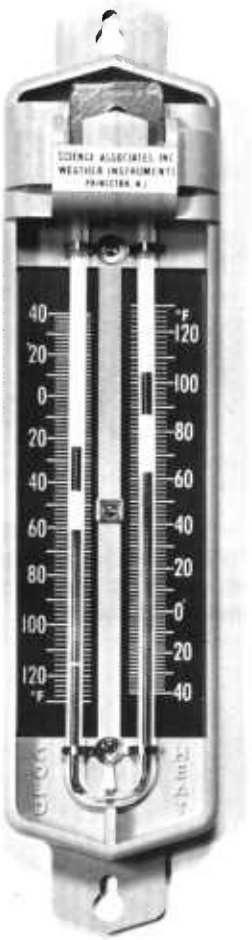


Figure 1.3. — Six's type maximum-minimum thermometer. Maximum temperature is read on the right, minimum temperature is read on the left.

1.2 INSTRUMENT SHELTERS

The instrument shelter, or thermometer screen (thermoscreen), is a specially designed enclosure that minimizes radiant heat while allowing free movement of air past the instruments placed within. Thermometers properly exposed in such a shelter will give temperature readings that represent the temperature of the surrounding outside air.

The Cotton Region Shelter

The cotton region type instrument shelter (fig. 1.4) is standard at National Weather Service stations and is recommended for use at all fire-weather stations. It is constructed of wood and painted white both inside and out. It has a double roof, louvered sides, and slotted openings in the floor. The shelter sits on an open type wooden or aluminum stand. All of these features contribute to this shelter's ability to provide a desirable environment for the exposure of thermometers.

A variety of homemade instrument shelters of other than cotton region design are in use at many fire-weather stations. The continued use of these shelters is discouraged as they complicate comparison of data between stations.

CROSS REFERENCE: Installation and Exposure 8.1.

Portable Shelters

A variety of portable instrument shelters are used for fire-weather purposes. Some are small wooden shelters, others are standard-sized aluminum or plastic shelters. The adequacy of these shelters depends to a large extent on shelter design, the type of instrument being used, and the required accuracy of the data to be collected. They are not meant to be used at permanent stations but rather as alternatives to the cotton region shelter at temporary field locations.

A field installation of a portable aluminum weather shelter is shown in figure 1.5. This shelter knocks down to a compact size (fig. 1.6) for relatively easy carrying. It has the advantage of being full sized and of the general cotton region design. In addition, this shelter was calibrated against the cotton region type (USDA Forest Service 1964a).

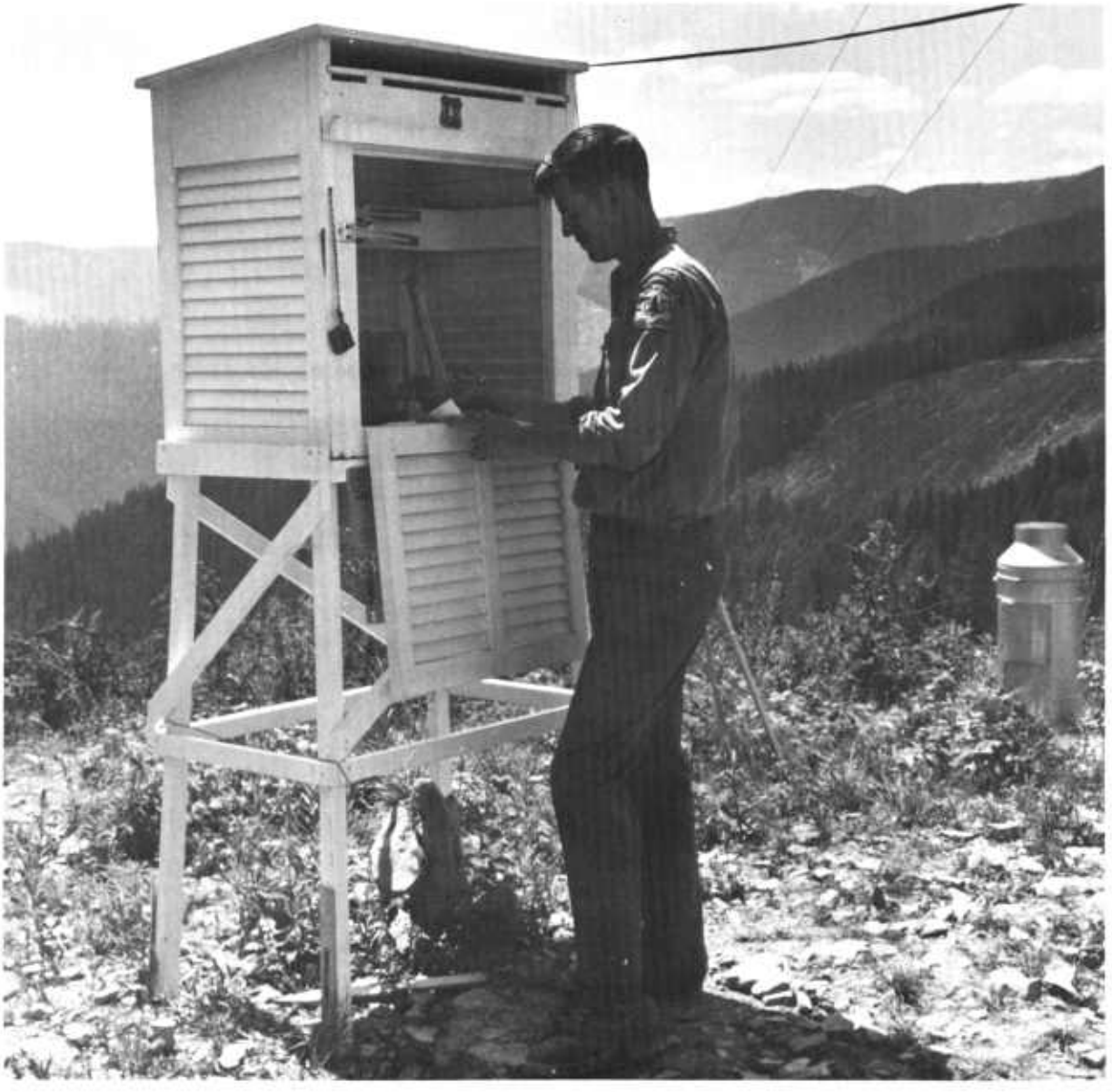


Figure 1.4. — Cotton region type instrument shelter. This standard design is recommended at all fire-weather stations.

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Figure 1.5. — A portable aluminum shelter installed at a temporary field station.

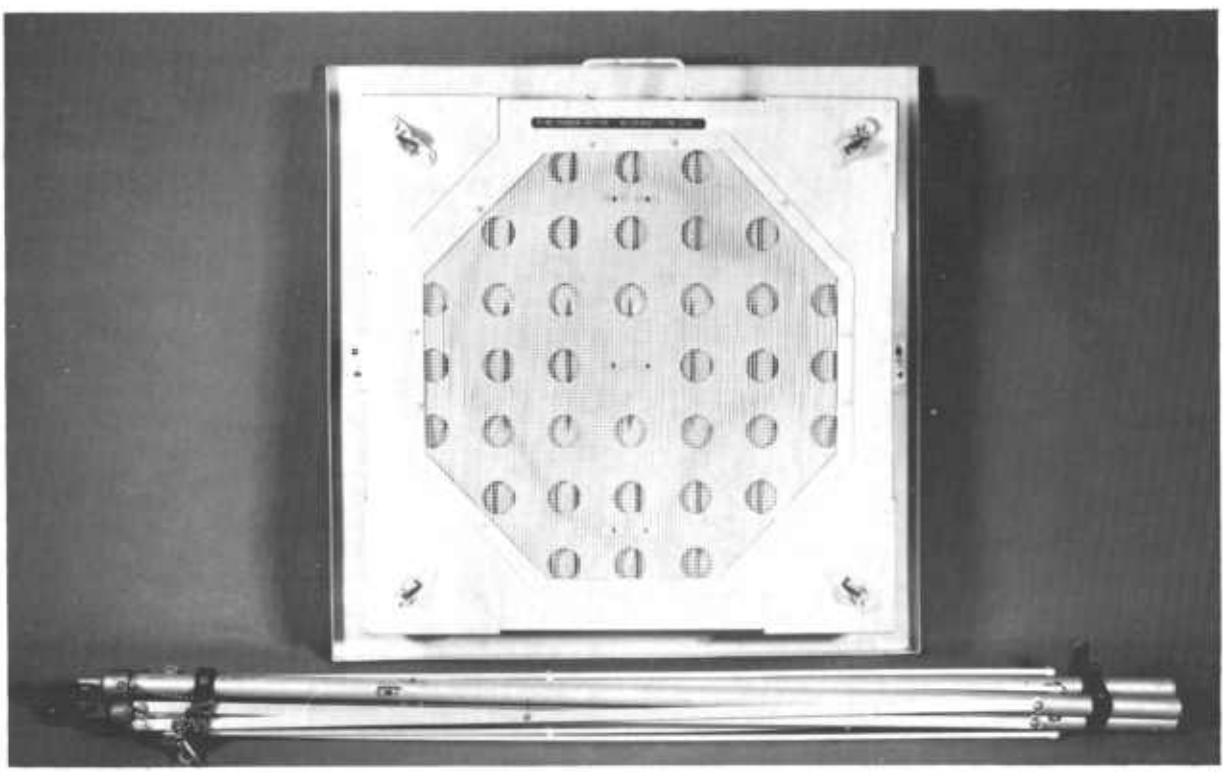
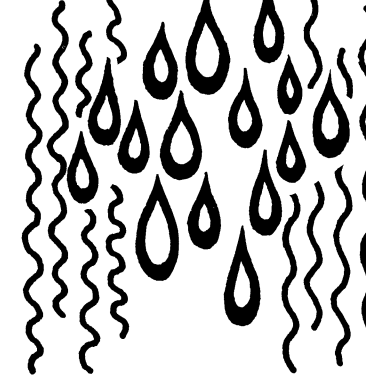


Figure 1.6. — Portable aluminum instrument shelter — knocked down for easy transport to the field.

CHAPTER 2

RELATIVE HUMIDITY AND DEWPOINT



Relative humidity (RH) is a ratio, expressed in percent (%), of the actual amount of water vapor in the air compared to the total amount of water vapor necessary for saturation.

The dewpoint temperature (DP) is the temperature (°F.) at which the air, if cooled, would reach saturation (100% RH). At this temperature, dew will start to form on a solid surface.

The dewpoint temperature and the wet- and dry-bulb temperatures will all be equal at 100 percent relative humidity.

To more fully understand what these factors represent and what they mean in terms of fire weather, the reader is urged to study Countryman's (1971) excellent discussion of relative humidity and dewpoint.

Relative humidity and dewpoint temperatures are usually recorded at least once a day at fire-weather stations. As mentioned previously, RH and DP are calculated from wet- and dry-bulb temperatures at the scheduled observation time. Maximum and minimum relative humidity are often recorded for the 24-hour period preceding the scheduled observation time. Maximum and minimum relative humidity is used to obtain an average relative humidity for the period of time they represent.

2.1 RELATIVE HUMIDITY AND DEWPOINT TABLES

Relative humidity and dewpoint values are determined from wet- and dry-bulb temperatures by use of National Weather Service "Relative Humidity and Dewpoint Tables," often referred to as "psychrometric" tables. Separate tables are provided for each of five levels of atmospheric pressure and elevation above sea level (table 2.1). Current National Weather Service Relative Humidity and Dewpoint tables are enclosed in the back of this book.

Another type of relative humidity table is based on the dry-bulb temperature and the wet-bulb depression. The wet-bulb depression is simply the difference in temperature between wet- and dry-bulb readings.

Table 2.1 — *Selection of psychrometric tables according to elevation above sea level*

Elevation above sea level		Psychrometric table
Alaska	All other States	Pressure
---------- *Feet* ----------		*Inches of mercury*
0 - 300	0 - 500	30
301 - 1,700	501 - 1,900	29
1,701 - 3,600	1,901 - 3,900	27
3,601 - 5,700	3,901 - 6,100	25
5,701+	6,101+	23

2.2 INSTRUMENTS

Instruments used at fire-weather stations for measurement of relative humidity and dewpoint are: (1) the psychrometer; (2) the wet- and dry-bulb hygrometer; (3) the mortarboard psychrometer; and (4) the hair hygrometer. Although use varies locally, the psychrometer is most often used for relative humidity measurement at fire-weather stations.

Psychrometers and wet- and dry-bulb hygrometers, including the mortarboard psychrometer, consist of two matched thermometers placed side-by-side on a common mounting plate. A thin cotton wick covers the bulb of one of the thermometers. When this wick is wet

and air passes over the thermometer bulbs, evaporation from the "wet bulb" will cause its temperature to drop. Assuming adequate ventilation (e.g., air movement across the wet bulb), the amount of evaporation from the wick depends on the moisture content of the surrounding air. The lower the relative humidity of the surrounding air, the greater the evaporation from the wet-bulb wicking; thus, a greater spread between the wet bulb's temperature and that of the dry bulb. The dry bulb indicates the temperature of the surrounding air. Regardless of the instrument used, wet- and dry-bulb readings are used to determine relative humidity percent and dewpoint temperature from standard psychrometric tables.

The hair hygrometer indicates relative humidity by recording on a calibrated scale (dial or chart) the changes in length of a human hair element and the corresponding changes in air moisture. The hair hygrometer is the humidity sensing element on hygrothermographs (section 2.3). The hygrothermograph is widely used to obtain a continuous record of maximum and minimum relative humidities at fire-weather stations.

The importance of adequate ventilation of the wet bulb cannot be overemphasized in relative humidity and dewpoint determinations. For this reason, artificially ventilated psychrometers are generally considered the most reliable of the four instruments mentioned.

The Psychrometer

Several types of psychrometers are used. They differ primarily in the method of ventilating the thermometers. Psychrometers used for fire-weather observations are: (1) the electric fan psychrometer (nonportable and portable); (2) the hand fan psychrometer; and (3) the sling psychrometer. All types consist of two carefully matched mercury thermometers having cylindrical bulbs and installed on a common mounting plate. All are designed to cool the wet bulb by forced ventilation.

Nonportable Electric Fan Psychrometer

A nonportable battery-operated electric fan psychrometer is shown in figure 2.1. When solidly mounted inside a suitable instrument shelter, it can provide consistently accurate wet- and dry-bulb measurements. Its use is recommended at all permanent fire-weather stations. The primary advantage of this psychrometer is that effective ventilation is easily accomplished. Since tiresome hand cranking or slinging is eliminated, observers are more likely to continue ventilation until the lowest wet-bulb reading is obtained.

Figure 2.1. — Electric fan psychrometer, USDA Forest Service type. This instrument is recommended for use at all permanent fire-weather stations.

CROSS REFERENCE: Installation and Exposure 8.3; Operation 11.1-11.2; Maintenance 17.1-17.4.

Portable Electric Fan Psychrometer

The portable, battery-powered fan psychrometer is designed for accurate determination of relative humidity and dewpoint in any location, at any time (fig. 2.2). It is usually supplied with a metal carrying case containing a padded section for the psychrometer and a separate compartment for accessories and spare parts. Some other features of this instrument include the following:

1. Fan is powered by ordinary "D" cell flashlight batteries.

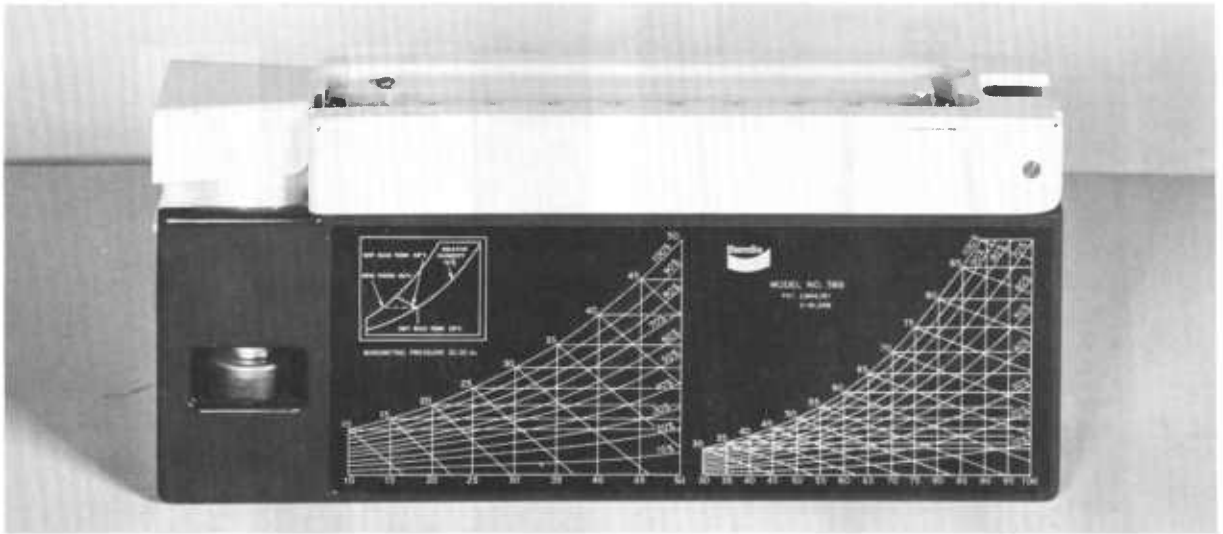


Figure 2.2. — Bendix "Psychron" portable electric fan psychrometer. This instrument allows accurate measurement of RH in the field.

2. Thermometers are recessed and are shock mounted with rubber fittings.

3. A light is built in for use at night.

4. Water bottle is stored in psychrometer housing.

5. Thermometer assembly can be removed and used as a sling psychrometer if electrical failure should occur.

CROSS REFERENCE: Operation 11.1-11.3; Maintenance 17.1-17.3, 17.6.

Hand Fan Psychrometer

The hand fan psychrometer is designed for use in an instrument shelter. Except for fan operation, it is identical to the electric fan psychrometer (fig. 2.3). Ventilation of the thermometers is accomplished by rapidly hand cranking the fan. To get accurate results, cranking must continue without interruption until the lowest wet-bulb reading is obtained.

CROSS REFERENCE: Operation 11.1, 11.4; Maintenance 17.1-17.3, 17.5.

Sling Psychrometers

The sling psychrometer is ventilated by whirling in a circular pattern around the hand of the observer. Sling psychrometers come in a variety of types (fig. 2.4). They differ mainly in the size and accuracy of the thermometers. Standard sling types are available with 12- or 9½-inch thermometers, graduated in

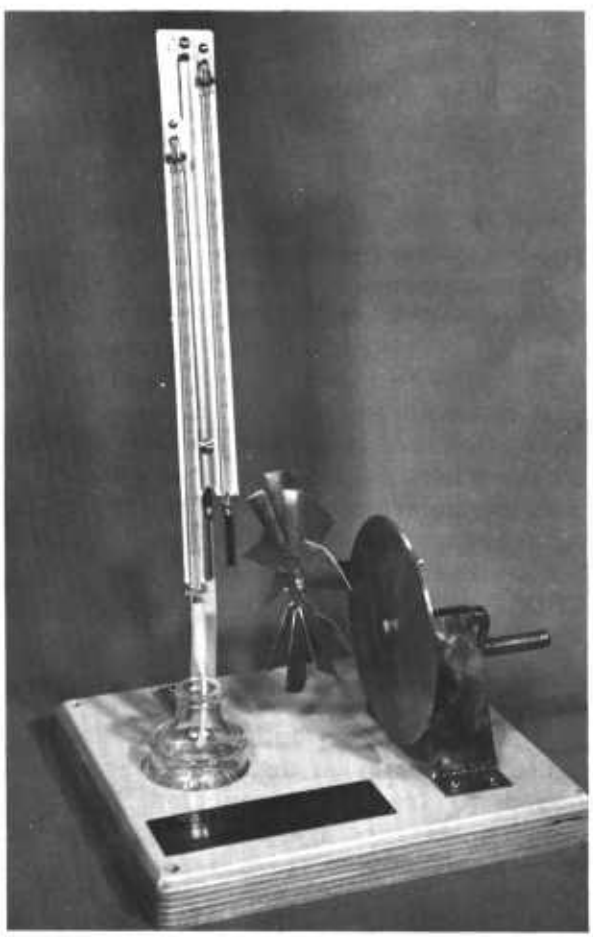


Figure 2.3. — Hand fan psychrometer, USDA Forest Service type.

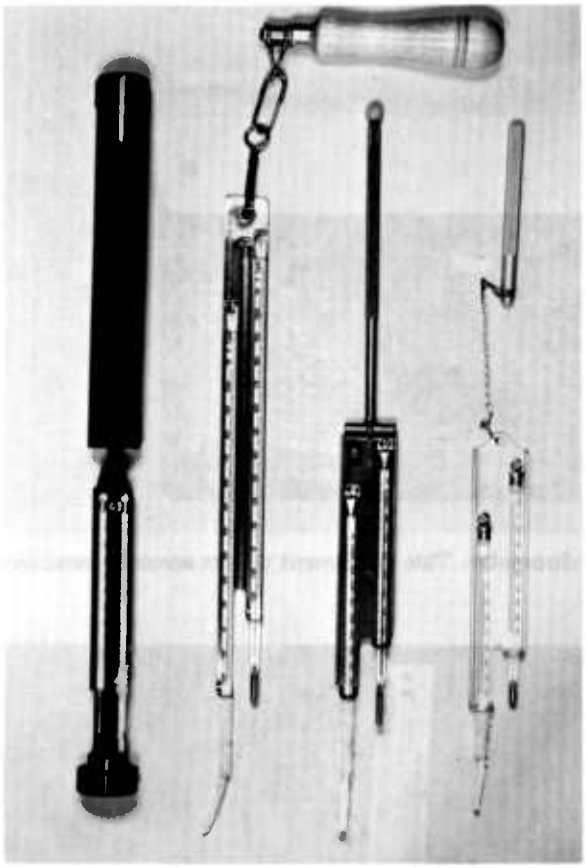


Figure 2.4. — Sling psychrometers. The standard 9½-inch psychrometer (second from left) is often kept as a "spare" at fire-weather stations.

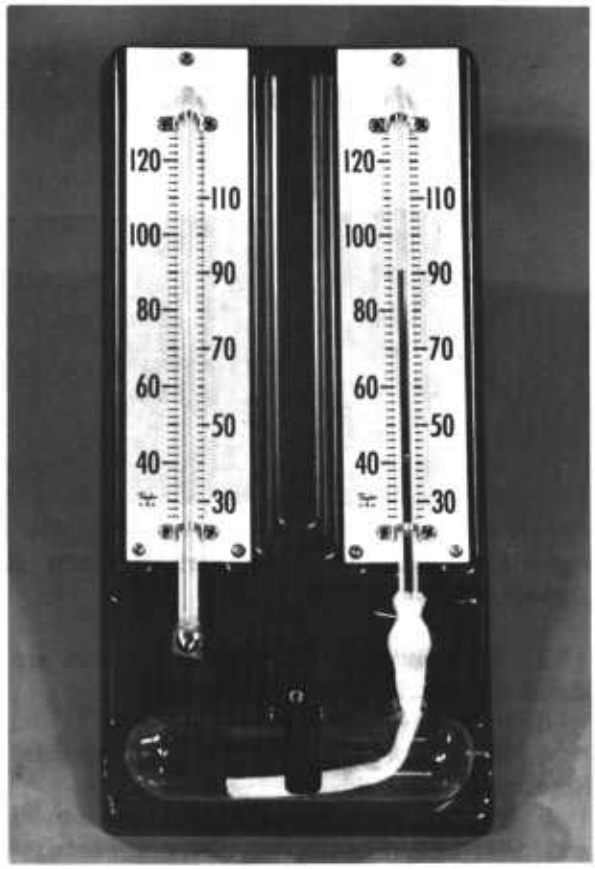


Figure 2.5. — Wet- and dry-bulb hygrometer. The glass reservoir on the bottom must be kept full of water.

0.1° F., 0.5° F., or 1° F. divisions. The 9½-inch thermometers with 1° F. divisions are more often used at fire-weather stations than are the others. Pocket types usually have 5½-inch thermometers and 2° F. graduations. A pocket sling psychrometer is provided in the belt weather kit (USDA Forest Service 1959). *CROSS REFERENCE: Operation 11.1, 11.5; Maintenance 17.1-17.3, 17.8.*

The Wet- and Dry-Bulb Hygrometer

The wet- and dry-bulb hygrometer is designed for use in an instrument shelter exposed to free air circulation. Like the psychrometer, the hygrometer operates on the principle of cooling by evaporation. Ventilation, however, is meant to be accomplished by the natural movement of the surrounding air.

The instrument consists of two spherical bulb thermometers, usually with 2° F. graduations, mounted side-by-side on a common backing. The wet bulb is covered by a wick which extends into a water container continually while the hygrometer is in service (fig. 2.5). Some hygrometers utilize a built-in glass water reservoir while others make use of a glass jar placed beneath the wet bulb. A thin plastic oilcan with the spout cut short has been recommended as the most desirable water container because: (1) the water level can be seen at a glance; (2) evaporation is reduced to a minimum; and (3) there is little chance of it being burst with light frosts (Williams 1964).

Relative humidity and dewpoint determinations obtained by using the wet- and dry-bulb hygrometer generally do not approach the accuracy of those obtainable from psychrometers due to the following:

1. Thermometers with 2° F. graduations may not have a full scale accuracy of better than ±2° F.

2. The small, spherical bulbs on the thermometers of most models tend to be sluggish in response to atmospheric changes.

3. Airflow across the thermometers may be inadequate if artificial ventilation is not used.

In order to achieve the maximum accuracy possible with the wet- and dry-bulb hygrometer, the thermometers should be fanned for about 3 minutes prior to reading and the thermometers should be read to the nearest 1° F.

CROSS REFERENCE: Operation 11.6.

The Mortarboard Psychrometer

The mortarboard psychrometer was developed at the Southern Forest Fire Laboratory to provide a simple, accurate, yet inexpensive means of obtaining wet- and dry-bulb temperature readings (Taylor 1963). It consists of an upper and lower radiation shield, a dry-bulb thermometer, a naturally ventilated wet-bulb thermometer, and supporting members. Water is continuously supplied to the wet bulb by a wick running from the wet bulb to a capped plastic cup mounted on the lower radiation shield (fig. 2.6).

CROSS REFERENCE: Operation 11.1, 11.7; Maintenance 17.1-17.3, 17.7.

2.3 THE HYGROTHERMOGRAPH

The hygrothermograph simultaneously and continuously measures and records air temperature and relative humidity. Several models are in common use at fire-weather stations. Although details of construction vary according to manufacturer, general operating principles are quite similar. All hygrothermographs consist of four major working parts (fig. 2.7):

1. A temperature element.
2. A relative humidity element.
3. Pen arm assemblies.
4. A chart drive mechanism.

The chart drive mechanism is basically a clock, either spring wound or battery driven, which turns a chart-holding drum. The clock is located either inside the drum and turns with it or is fixed to the base of the instrument and the drum revolves around it. The pen arm assemblies are simply the link between the chart and the temperature and humidity sensors.

The Temperature Element

The hygrothermographs that are most commonly used today contain deformation thermometers for measuring temperature. Either a curved Bourdon tube or a bimetal strip that is curved or coiled forms the

Figure 2.6. — The mortarboard psychrometer. This instrument is widely used in the Eastern United States.

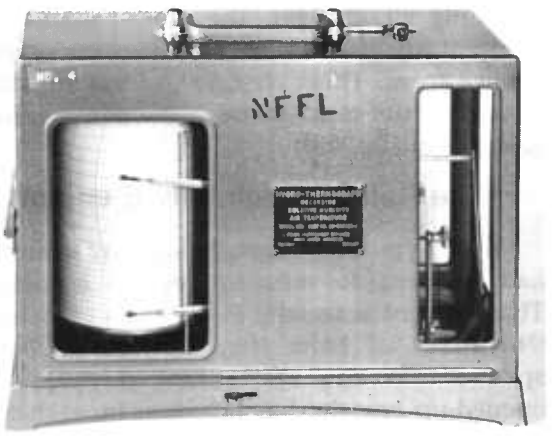


Figure 2.7. — The hygrothermograph. The upper pen records temperature; the lower pen records relative humidity.

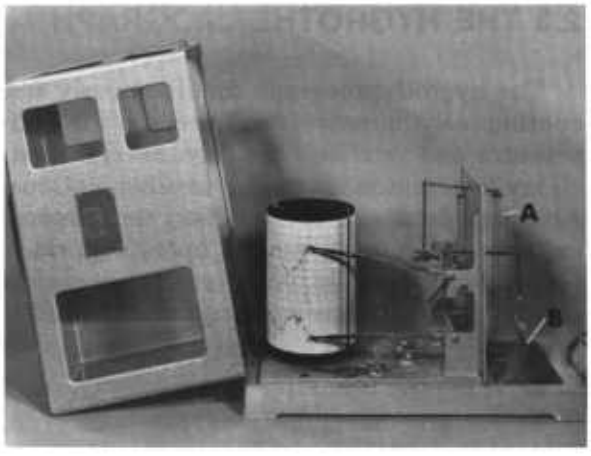


Figure 2.8. — Hygrothermograph equipped with (A) banjo spread hair element and (B) Bourdon Tube.

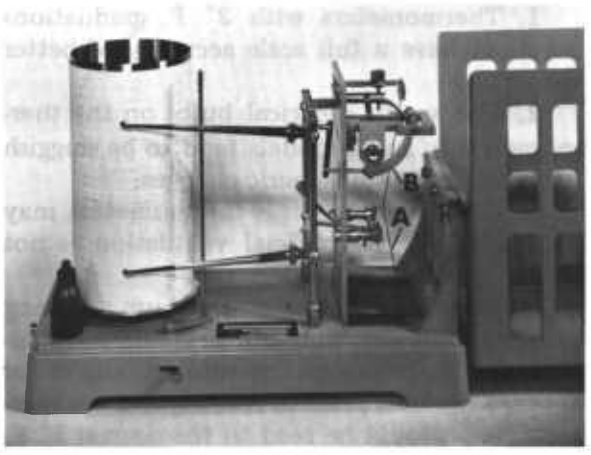


Figure 2.9. — Hygrothermograph equipped with (A) hair bundle element and (B) bimetal strip.

temperature-sensitive element of these thermometers.

The Bourdon tube, slightly elliptical in cross section, is filled to capacity with an organic fluid. One end of the tube is fixed to the hygrothermograph base and the other to the temperature pen arm linkage. As the temperature of surrounding air varies, the liquid in the tube expands or contracts causing the Bourdon tube to stretch out or curl up accordingly. These changes in form are transmitted to the chart through the pen arm linkage system (fig. 2.8).

The bimetal strip is formed by a welding of two different metals that have dissimilar expansion rates. As temperature of the surrounding air changes, the metals expand or contract at different rates causing the strip to change form. These changes in form are transmitted to the chart through the pen arm linkage system (fig. 2.9).

The Relative Humidity Element

Most hygrothermographs employ a human hair element to measure relative humidity. This element is usually in the form of either a "bundle" of hairs (fig. 2.9) or a "banjo spread" arrangement that resembles an opened-up bracelet having clasps on each end. (fig. 2.8).

The operating principle of these hygrothermographs is the same; high humidity results in a lengthening of the hair while low humidity causes the hair to shorten. The movements of the hairs are transmitted to the chart through the pen arm linkage system.

The Chart Record

The temperature pen records on the upper part of the chart and relative humidity pen on the lower part (fig. 2.10). Several temperature chart scales are available but two are in common use: +10° to +110° F. for summer use and -30° to +70° F. for winter use. The relative humidity scale covers the full range from 0 to 100 percent.

Daily, weekly, and monthly charts are available. The chart must correspond to the gear ratio or drum rotation of the instrument. The gear ratio can be easily changed from daily to weekly drum rotation, or weekly to daily, by changing the gears on both the drum and the arbor to correspond to the desired chart time. Weekly charts are most often used at fire-weather stations. To obtain a monthly record, an additional chart drive mechanism is usually required in addition to the required gears.

Hygrothermograph charts have either square or tapered ends. Only the tapered-end charts can be used on clock cylinders that have a vertical slot in the cylinder wall. The ends of the chart are inserted into this slot and held in place by a metal retainer that presses the chart ends to the right and left against the inside of the cylinder wall.

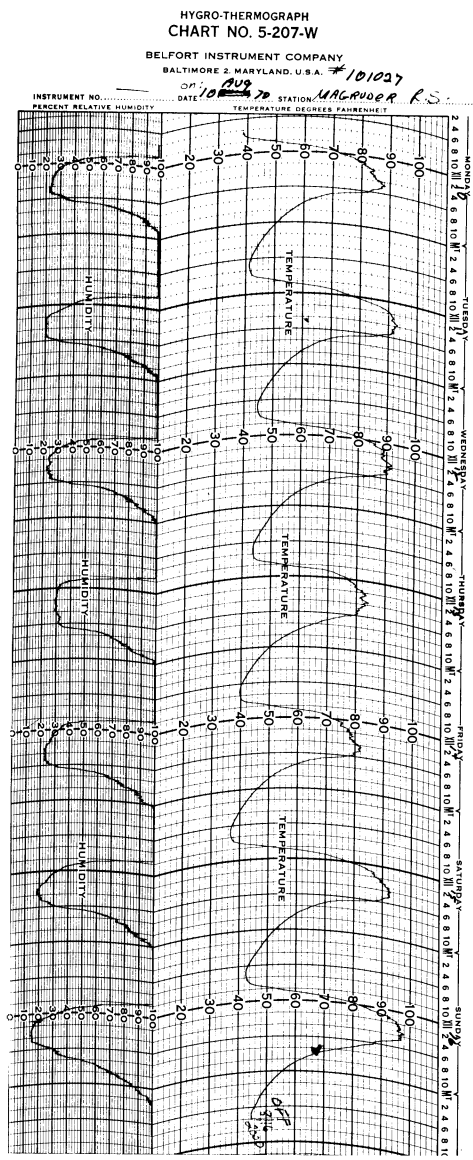


Figure 2.10. — Weekly chart record from a hygrothermograph — temperature record is on upper half of chart; relative humidity record is on lower half.

Both square- and tapered-end charts can be used on the more common nonslotted clock cylinders. Both types of charts are retained by a metal clip that holds the chart to the outer wall of the cylinder. Although square-end charts are most commonly used on nonslotted cylinders, the tapered-end charts have the advantage of covering the clips that hold them in place. This eliminates loss of data when the cylinder is allowed to go beyond one revolution before changing charts.

Reliability

The reliability of its data depends directly on the hygrothermograph's calibration and maintenance. If the instrument is precisely calibrated and given continuous maintenance, an acceptable[1] level of accuracy can be expected most of the time. This is especially true for temperature data. Relative humidity readings tend to be less reliable because of calibration difficulties and due to certain inherent characteristics of human hair.

A recent test (Meeks 1968) showed a rather uniform standard hygrothermograph error ranging from ±2 to ±5 percent relative humidity. The results show that, in general, the hygrothermograph records too low at high humidities and too high at low humidities.

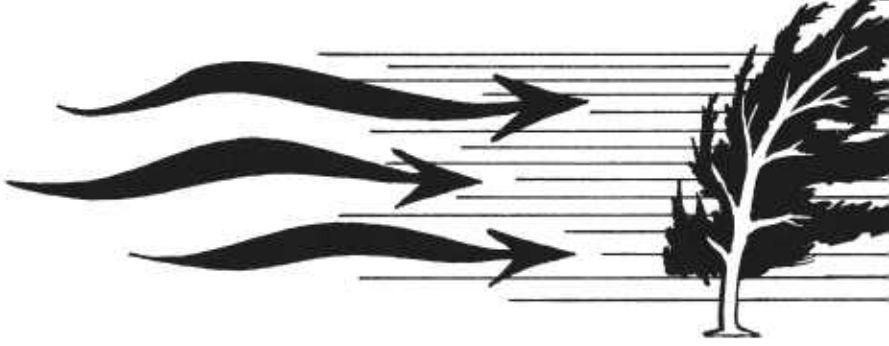
Often the greatest loss of reliability in relative humidity data occurs at times of major weather changes. At these times, loss of calibration often results from the inability of the hairs to accommodate themselves to the new humidity regime.

CROSS REFERENCE: Installation and Exposure 8.4; Operation 12; Maintenance 18.

[1] *Plus or minus 3 percent relative humidity and ±0.5° F. temperature (World Meteorological Organization 1969).*

CHAPTER 3

WIND



Wind is air in motion. This motion, or velocity, has two components: windspeed and wind direction.

Windspeed refers to the rate at which air passes a given point. Fire-weather measurements of windspeed are expressed in statute miles per hour (m.p.h.).

Wind direction refers to the direction **from** which the wind is blowing. This direction is recorded, often in coded form, as azimuth degrees from true north (0° to 360°) or compass points (N, NE, E, SE, etc.).

3.1 WINDSPEED

Fire-weather measurements of windspeed are obtained from cup anemometers exposed at the standard height of 20 feet above open, level ground (fig. 3.1). This standard height must be adjusted to compensate for height of ground cover, surface irregularities, and nearby obstructions (see section 8.7).

Cup anemometers are calibrated to rotate at a rate proportional to the actual windspeed. This rotation is transferred by the main shaft to either a contacting mechanism or a generator, depending on the type of anemometer. Either the number of contacts being made, or voltage generated, is read out on a recording or indicating device wired to the anemometer. The readout device can be located either at the weather station or in a nearby office.

Contacting-type anemometers are used almost exclusively at fire-weather stations. Generator-type anemometers are commonly used only where instantaneous readout of actual windspeed is desired.

Contacting Anemometers

Contacting anemometers consist of four major parts: a 3- or 4-cup rotor assembly; a main vertical shaft or spindle; a gear mechanism; and an electrical contact. In addition, some contain a built-in dial or counter which records and accumulates total wind movement.

Figure 3.1. — Anemometer (windspeed) and wind vane (wind direction) exposed at 20-foot standard height at a fire-weather station.

Figure 3.2. — The small Airways anemometer with 1/60-mile contacts is used at many fire-weather stations.

vance of the counter indicates a closing of the anemometer contact. The count per minute, therefore, can be read directly as windspeed in miles per hour.

CROSS REFERENCE: Installation and Exposure 8.5; Operation 13.1; Maintenance 19.

Mechanical Counters

The mechanical counter is preferred over the buzzer or flasher because the chance of miscounting is greatly reduced, especially when windspeed is averaged over a period of more than a few minutes. These counters are of three general types: nonreset; reset (fig. 3.3); and reset with 10-minute timer (fig. 3.4). The reset types can be set at zero at the beginning of each observation and thus can be read directly at the end of the prescribed ob-

Figure 3.3. — Mechanical counters in use at fire-weather stations: *Left and center*, Nonreset types; *right*, reset type.

Anemometers Equipped With 1/60-Mile Contacts

The most popular contacting anemometers are geared to close a contact after 1/60 mile of wind passes the cups (fig. 3.2). The number of contacts per minute, therefore, represents the windspeed in miles per hour.

Readout is obtained by wiring a buzzer, flasher, or more commonly, a mechanical counter to the binding posts located on the anemometer housing. Each buzz, flash, or ad-

Figure 3.4. — Reset type mechanical counter with timer simplifies determination of 10-minute average windspeed.

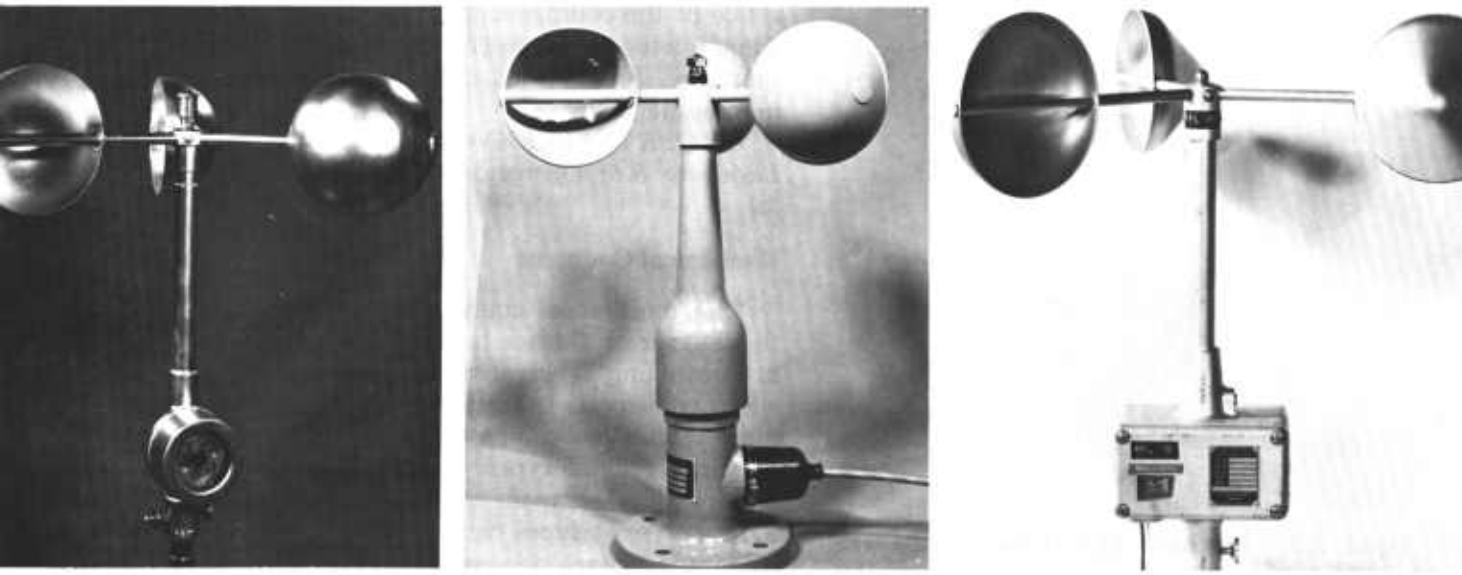


Figure 3.5. — Totalizing-type anemometers equipped with both 1/60-mile and 1-mile contacts: *Left*, Self-contained dial readout; *center*, without self-contained readout; *right*, self-contained counter readout.

servation period. The reset type equipped with a timer further simplifies the observer's task because it records for only the period of time desired.

CROSS REFERENCE: Installation and Exposure 8.6; Operation 13.1; Maintenance 20.

Anemometers Equipped With 1-Mile Contacts

Some anemometers have 1-mile contacts instead of, or in addition to, 1/60-mile contacts (fig. 3.5). Operation is similar to anemometers with 1/60-mile contacts except that one contact is made for each 1 mile of wind passing through the cups. The number of contacts per hour, therefore, gives the windspeed in miles per hour. Usually the ninth and tenth pins of the contact wheel are bridged to give a longer contact for each 10 miles of wind passage. One-mile contacts are often used to obtain extended-period chart records of wind movement. Special totalizing counters are available for readout of anemometers with 1-mile contacts.

CROSS REFERENCE: Installation and Exposure 8.5; Operation 13.2; Maintenance 19.1-19.4, 19.11-19.13.

The Hygrothermoaerograph

Anemometers with 1-mile contacts can be used in conjunction with a hygrothermoaerograph to obtain a chart record of wind movement on a time scale. A hygrothermoaerograph (HTAG) is simply a conventional hygrothermograph that has been modified by the addition of a third arm to record wind movement and temperature and relative humidity (Fischer, Beaufait, and Norum 1969), as shown in figure 3.6. See Appendix for wiring diagram and construction detail.

Anemometers Equipped With Self-Contained Readout

Some anemometers are constructed with a self-contained readout device that is driven directly by the anemometer spindle (fig. 3.5). This readout device may be in the form of a counter or a dial.

In the counter type, the spindle drives a four- or five-digit counter that indicates total wind movement. Depending on the specifications when purchased, readout will be in statute miles, nautical miles, or kilometers. Statute miles are used for fire-weather observations. Since the counter operates as long as the anemometer is in service, a reading must be taken at the beginning and ending of any period for which data are required. To find average windspeed, divide the elapsed count by the elapsed time in hours.

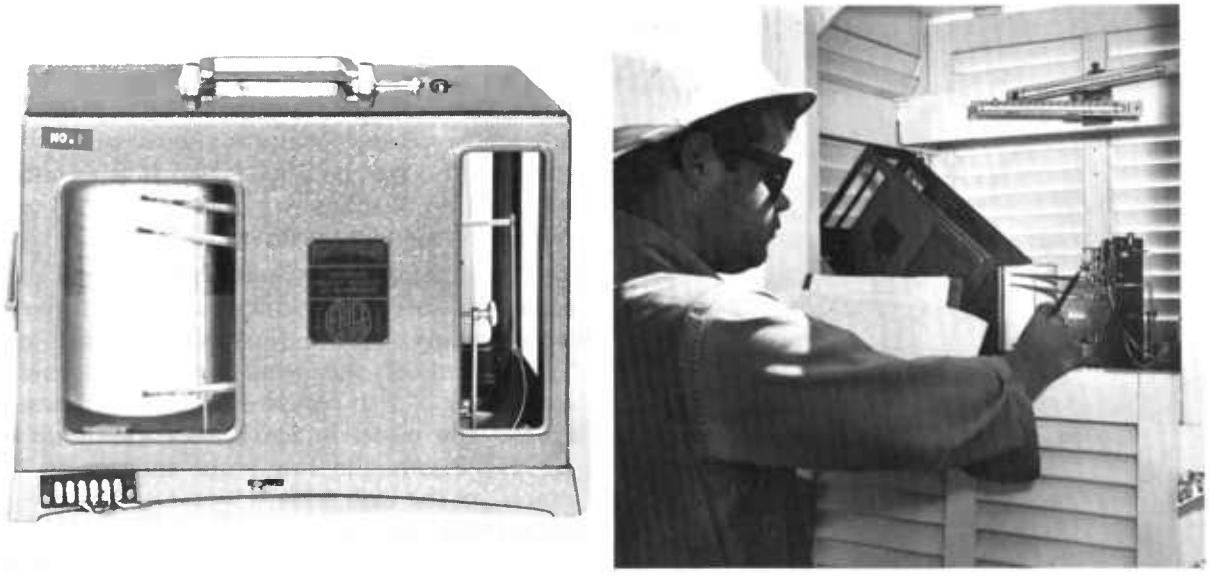


Figure 3.6. — A hygrothermoaerograph (HTAG). Uppermost pen arm has been installed to record wind movement.

In the dial type, the dials are composed of two thin wheels, one rotating on top of the other. The inner dial is graduated in tens and hundreds of miles. The outer dial is graduated in miles and tenths of miles (fig. 3.7).

CROSS REFERENCE: Installation and Exposure 8.5; Operation 13.2; Maintenance 19.1-19.4, 19.11-19.13.

Generator Anemometers

Generator anemometers consist of a rotor or cup assembly, a vertical shaft, a generator, and a windspeed-indicating device. The shaft connects the cups to a small permanent magnet generator. As the cups rotate, voltage is generated in proportion to the windspeed. Instantaneous indication of the windspeed is obtained from an attached voltmeter calibrated in terms of miles per hour (figs 3.8 and 3.9). It is usually difficult to obtain an average windspeed value from generator anemometers. Rough estimates can be obtained by observing a series of dial indications over a short period and averaging the individual indications. Such estimates are not generally acceptable for fire-danger rating purposes. Average wind data of improved accuracy can be obtained from chart records produced by some generator anemometers. The windspeed required to start the cups rotating is relatively high for many popular-priced generator anemometers (i.e., 5 to 6 m.p.h. compared to 2 to 3 m.p.h. for some contact types). These characteristics should be taken into consideration when selecting instruments.

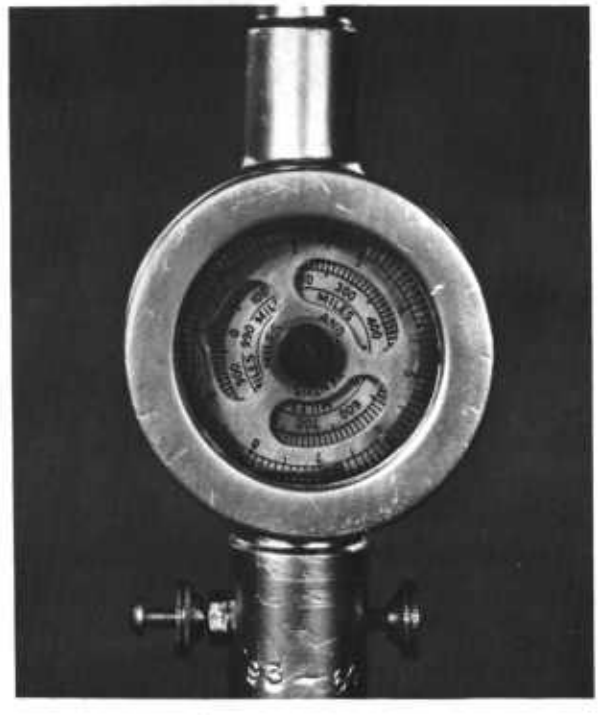


Figure 3.7. — Dial on this anemometer accumulates total wind movement past anemometer cups.

Figure 3.8. — Generator anemometer with remote dial readout is useful whenever instantaneous windspeed measurements are desired.

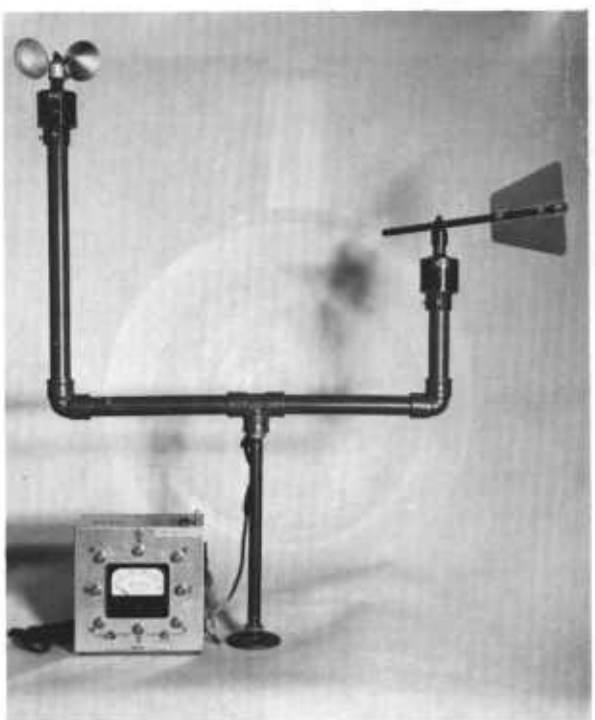


Figure 3.9. — Wind system; anemometer on left, wind vane on right. Remote readout device shows windspeed (dial) and wind direction (lights).

Hand-Held Wind Meter

This highly portable venturi action wind meter is a simple instrument designed for quickly obtaining the approximate windspeed close to the ground (fig. 3.10). It is accurate within 1 or 2 miles per hour and is a component of the belt weather kit.

The slightly tapered outer plastic shell contains a double scale and a small plastic tube in which a tiny white indicator ball is enclosed. The action of the wind around the meter causes the ball to rise in relation to the windspeed. The meter indicates windspeeds up to 10 m.p.h. on the low scale and up to 60 m.p.h. on the high scale.

CROSS REFERENCE: Operation 13.4; Maintenance 19.14.

Figure 3.10. — Hand-held wind meter provides easy wind measurement near the ground.

3.2 WIND DIRECTION

Wind direction can be obtained quite simply by facing into the wind or by observing the effect of the wind on smoke columns, blowing dust, tree leaves, and other vegetation. Flags make good wind direction indicators and can be obtained near many fire-weather stations. Colored plastic flagging tape tied to the anemometer pole also makes a satisfactory wind direction indicator. When estimating wind direction, the observer should be directly underneath the indicator, or as close as possible to this position. This will minimize errors due to perspective. The success of any of the methods depends on the observer's knowledge of the cardinal directions or his use of a compass. Accuracy of observations can be improved by establishing a north reference at each station.

Wind Vanes

The meteorological instrument, or wind vane, used for measuring wind direction is an asymmetrically shaped pointer or arrow mounted on a vertical shaft (figs 3.1 and 3.9). The arrow will turn freely in very light winds.

Many wind vanes at fire-weather stations indicate wind direction by simply pointing into the direction of the wind. Other types of wind vanes transmit their indications by electrical contacts, resistor circuits, etc. Readout is usually a series of eight lamps, or dial indicators, one each representing N, NE, E, SE, S, SW, W, and NW (fig. 3.9).

CROSS REFERENCE: Installation and Exposure 8.7; Maintenance 21.

CHAPTER 4

PRECIPITATION

Precipitation is the amount of water falling upon the earth as rain, snow, sleet, hail, etc. It is measured by determining the depth, in inches, that accumulates over a flat surface.

4.1 INSTRUMENTS

Precipitation is collected and measured in a rain and snow gage. Most rain gages consist of a right cylinder of known cross section, having straight sides and a sharp upper edge. This cylinder often has an inner measuring tube in which the amount of water can be either read directly or measured with a graduated dipstick.

Three types of rain gages are used for fire-weather measurement of precipitation: (1) the standard 8-inch-diameter rain gage; (2) the small orifice rain gage; and (3) the recording rain gage.

The Standard 8-Inch Rain Gage

The components of a standard-type rain gage are shown in figure 4.1. The collector, or top section, is 8 inches inside diameter at the rim and is funnel-shaped at the bottom to channel the "catch" into the measuring tube. It also aids in reducing evaporation of collected water.

The circular area of the measuring tube is one-tenth the area of the collector; therefore, the depth of water within this part of the tube magnifies the actual precipitation 10 times, allowing greater precision of measurement.

The measuring stick is marked in inches and tenths. Each 1/10 inch on the sticks represents 0.01 inch of precipitation.

Types of Standard Gages

Two types of standard rain gages are available: the traditional, large capacity, rain and snow gage (fig. 4.2); and the less expensive but lower capacity Forest Service rain gage (fig. 4.3). As indicated, they differ primarily in capacity. The traditional type holds up to 2 inches of precipitation in its measuring tube and a total of 20 inches in the overflow cylinder. The Forest Service type holds up to one-half inch of precipitation in its measuring tube and a total of 7 inches in the overflow cylinder.

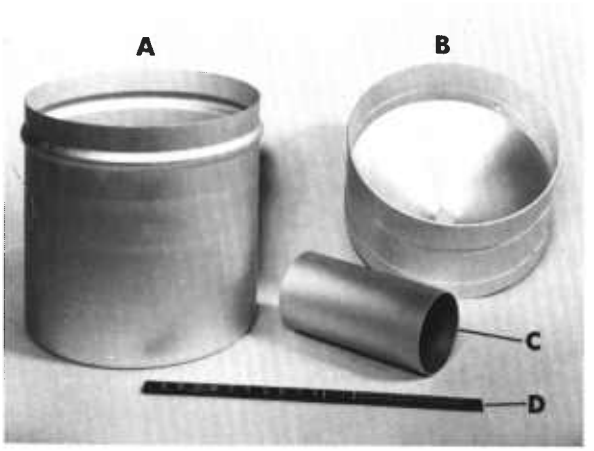


Figure 4.1. — Components of the standard 8-inch rain gage (USDA Forest Service type): *A*, Overflow cylinder; *B*, collector; *C*, measuring tube; *D*, measuring stick.

Figure 4.2. — Large capacity National Weather Service standard 8-inch rain gage.

Figure 4.3. — Low capacity USDA Forest Service rain gage was designed for use in areas of low summer rainfall.

It was designed to provide an economical instrument for use in those areas where 24-hour rainfall seldom exceeds a few inches.

Measuring Sticks

Measuring sticks of either red gum wood or laminated plastic are used for both types of standard gages. The plastic stick has several advantages over the wood stick: (1) water will not creep up the stick; (2) the plastic stick and its markings are more durable; and (3) the plastic stick can be easily washed clean of oil, dirt, or grease. The waterline on the wood stick, on the other hand, is much easier to see than on the plastic stick and since the water is more likely to be absorbed by the wood, there is less chance of erroneous readings due to the waterline being displaced.

Mounts

Traditional type rain gages are mounted in either a steel tripod stand or a wooden stand, which is often shaped from their shipping con-

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tainer. The Forest Service rain gage is usually mounted in a wooden stand as illustrated in figures 4.2 and 4.3.

CROSS REFERENCE: Installation and Exposure 8.8; Operation 14.1; Maintenance 22.1.

The Small Orifice Rain Gage

Rain gages designed with small openings and reduced water storage capacities are often used to collect supplemental rainfall data in areas that are some distance from the main weather station. Most of these gages are made of durable plastic and have the advantage of low cost and easy portability. A survey of the literature dealing with small orifice rain gages (Corbett 1967) shows:

1. Accuracy of some gages compares favorably to the standard 8-inch rain gage.
2. Under certain conditions, a more accurate estimate of rainfall can be obtained because these gages do not obstruct the flow of air as much as a large gage.
3. Most are unsuitable for snow measurement.
4. Use during freezing weather is not recommended.
5. Evaporation loss is relatively high; hence, these gages should be read as soon as possible after precipitation ends.

Most small orifice rain gages are designed as direct reading instruments and do not require a measuring stick.

Several of the more common types of small orifice rain gages are shown in figures 4.4 and 4.5. Two models considered suitable for certain fire-weather applications are described below.

Four-Inch Clear Plastic Gage

This gage is modeled after the traditional type, 8-inch-diameter gage (fig. 4.5). It consists of a 4-inch-diameter, knife-edged, funneled collector, an overflow cylinder, and a direct reading measuring tube. All parts are made of a clear, durable, plastic type material. The collection tube has 0.01-inch graduations and holds 1 inch of rain; the overflow cylinder holds an additional 10 inches. The gage is supplied with a stainless steel mounting bracket for attachment to a post or stake.

CROSS REFERENCE: Operation 14.2; Maintenance 22.1.

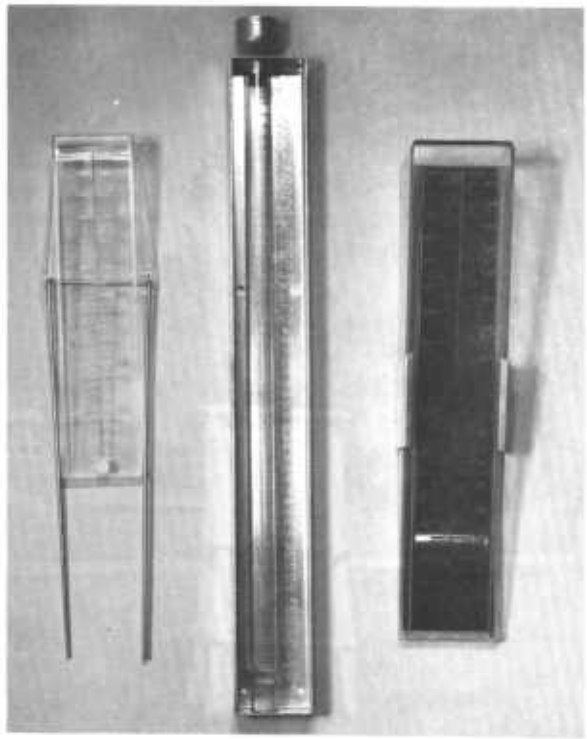


Figure 4.4. — Several types of direct reading small orifice rain gages.

Figure 4.5. — Four-inch clear plastic direct reading rain gage.

Wedge-Shaped, Fencepost, or Farmer's Gage

This unit is a smooth, one-piece molding of durable plastic. It consists of a wedge-shaped well on which a scale is printed (fig. 4.4). The knife-edged opening at the top of the gage is 2.5 by 2.3 inches. The scale is graduated in units of 0.01 inch. The gage has a capacity of 6 inches of precipitation. It is supplied with a bracket for mounting on a post or stake. Measurement is by direct observation of the water level in the well. Evaporation loss can be quite high in this gage. Both the unfunneled open top and the tendency for small amounts of water to cling to the sides account for this high loss. The gage does have an advantage because it will provide more accurate measurement of small amounts of rain than will the 8-inch-diameter gage. However, to capitalize on this advantage, this gage must be read very soon after the rain stops.

CROSS REFERENCE: Operation 14.3; Maintenance 22.1.

The Recording Rain Gage

Recording rain and snow gages provide graphic information which can be used to determine the time duration, intensity, and amount of precipitation for each storm or occurrence as well as the total amount of precipitation during any given time period.

There are two kinds of recording rain gages in common use: the weighing type; and the tipping bucket type. Both consist of four main parts: a collector; a measuring mechanism; a recording mechanism; and a housing.

The Weighing Rain Gage

The weighing type rain gage is by far the most widely used recording gage at fire-weather stations. The operating principle is relatively simple.

On the standard Fergusson type rain gage (fig. 4.6), the knife-edged collector is 8 inches (inside diameter) at the top and has a removable funnel at the bottom. As rain is caught by the collector, it is funneled into a 12-quart bucket which rests on the platform of a spring scale weighing mechanism.

The weight of the collected precipitation entering the bucket is instantaneously transmit-

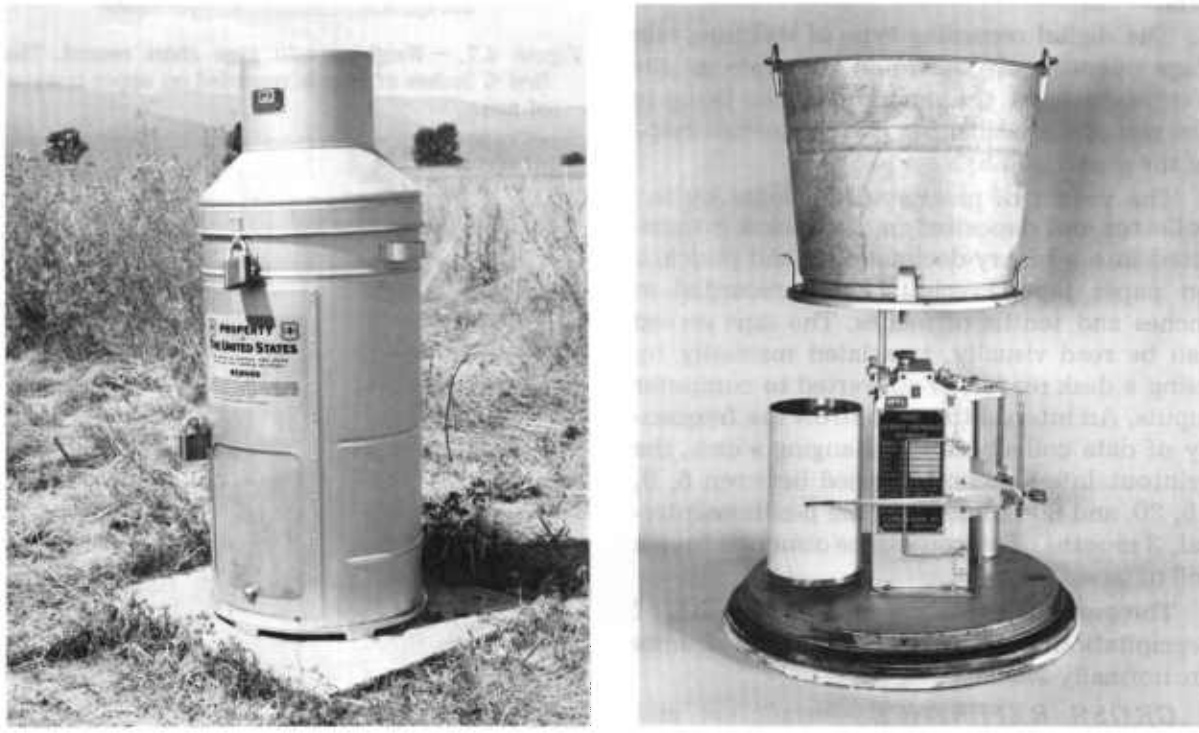


Figure 4.6. — Fergusson type weighing rain gage: *Left*, Assembled gage; *right*, weighing and recording mechanisms.

ted through a linkage system to the pen arm and onto the chart (fig. 4.7). A dash pot is provided in the linkage system in order to dampen any pen arm oscillations caused by wind or other sources of vibration.

The pen arm records the weight of the catch in equivalent inches of precipitation. Gages can usually be calibrated to record a total of 2.4, 6, 9, 12, or for the full capacity of 20 inches of precipitation. Standard calibration is for 12 inches of precipitation. In this case, each inch of record equals 1 inch of rainfall. Recording is accomplished by a dual traverse of the pen arm; the first 6 inches being recorded on the upstroke of the pen and the second 6 inches on the downstroke.

The spring wound chart drive is similar to those used in hygrothermographs (see section 2.3). Like the hygrothermograph, the chart time scale can be varied by gear selection. Daily, weekly, and monthly intervals are normally available.

The housing encloses the entire operating mechanism and the collector serves as the top. A sliding door is provided at the bottom of the housing for access to the chart drive and pen arm.

The digital recording type of weighing rain gage operates on the same principle as the Fergusson type, the main difference being in the recording mechanism and the overall shape of the gage (fig. 4.8).

The weight of precipitation caught by the collector and deposited in the bucket is translated into a binary-decimal code and punched on paper tape. Precipitation is recorded in inches and tenths of inches. The tape record can be read visually, translated manually by using a desk reader, or converted to computer inputs. An interval timer controls the frequency of data collection. By changing a cam, the printout interval can be varied between 5, 6, 15, 30, and 60 minutes. At the 5-minute interval, 3 months of record can be obtained from a roll of tape.

The gage has a total capacity of 20 inches of precipitation. Both a.c. and d.c. powered units are normally available.

CROSS REFERENCE: Installation and Exposure 8.9; Operation 14.4; Maintenance 22.3.

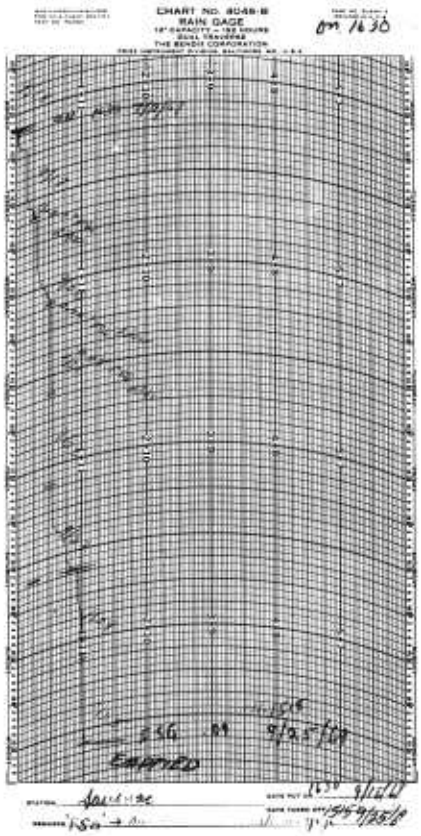


Figure 4.7. — Weighing rain gage chart record. The first 6 inches of rain is recorded on upper traverse of pen.

Figure 4.8. — Digital recording rain gage equipped with Alter shield.

The Tipping Bucket Rain Gage

The tipping bucket rain gage (fig. 4.9) is used primarily for remotely recording precipitation. Both 8-inch- and 12-inch-diameter models are available.

The operating principle of the tipping bucket gage is relatively simple. Precipitation is funneled from the collector through a small spout to a tipping bucket mechanism. The tipping bucket mechanism consists of two small buckets, each having a capacity of 0.01 inch of precipitation (fig. 4.10). The bucket under the spout fills to capacity, loses its balance, and tips. As the bucket tips, it closes a mercury switch which sends an electric impulse, representing 0.01 inch of precipitation, to a remotely located recorder. As the loaded bucket tips, the second bucket is positioned under the spout. The water from the tipping bucket is emptied into an overflow reservoir.

Several types of recorders can be used with the tipping bucket gage. The most popular is the spring-wound or battery-operated, clock driven, event recorder. The chart record shows precipitation by a stepped trace; each step represents 0.01 inch, or one tip of the bucket. After 1 inch of precipitation has been recorded, the pen drops to the bottom of the chart and starts a new trace. Some event recorders are equipped with a digital counter which shows total accumulated precipitation at a glance.

CROSS REFERENCE: Installation and Exposure 8.9; Maintenance 22.2.

Figure 4.9. — Tipping bucket rain gage.

Reliability of Recording Rain Gages

Observers are often perplexed when they encounter differences in catch between a recording rain gage and a nearby nonrecording gage; however, such differences are not unusual.

Studies show that recording gages equipped with sloping shoulders below the collector orifice will collect from 2 to 6 percent less precipitation than the standard nonrecording gage that has the shape of a right cylinder (Jones 1969).

Aside from collector shape or size of opening, the tipping bucket gage has additional features that can affect the reliability of catch data. During light rains in warm weather, water can accumulate in the receiving bucket slowly enough to allow losses from evaporation before

Figure 4.10. — Tipping bucket is visible inside the inspection door.

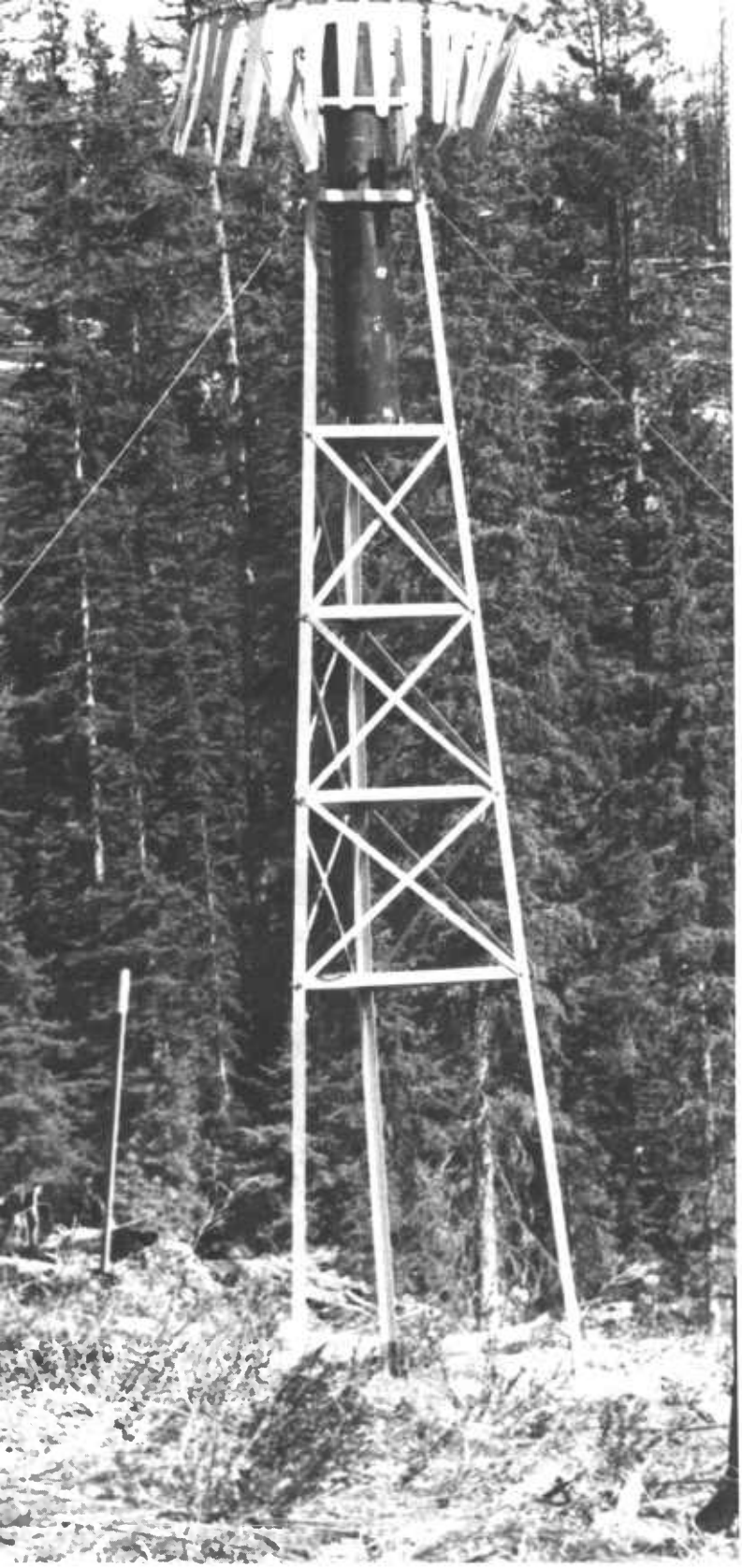


Figure 4.11. — Alter type rain gage shield mounted around a precipitation storage gage.

enough rain is collected to tip the bucket. In very heavy rainfall, some water loss can occur during the tipping operation; that is, more than 0.01 inch can be deposited in the tipping bucket before the empty bucket is in position to start receiving the steady stream of water.

Rain Gage Shields

Rain gages are often installed in situations where the effects of wind on precipitation catch cannot be minimized by site selection (see section 7.1). In such cases, a rain gage shield may be required. Two types of shields are in common use:

1. The trumpet-shaped Nipher type which attaches to the top of the rain gage, and
2. The Alter type which consists of a series of individual free-swinging baffles on a large steel ring (figs. 4.8 and 4.11). The Alter type has its own supports and is installed around the rain gage.

Both types of shields can successfully minimize the effects of wind on rainfall catch. Snow will often build up around the Nipher type shield, however, causing blockage of the rain gage opening. Because of this, the Alter type shield is highly favored at year-round stations in snow country.

The routine use of rain gage shields at fire-weather stations would improve the accuracy of precipitation catch. Some meteorologists believe that the most serious observational error at weather stations is caused by not using rain gage shields.

4.2 SUPPLEMENTAL INFORMATION

In addition to the amount of precipitation collected in the rain gage, the following supplemental information should be considered part of a complete precipitation record:

1. Kind of precipitation.
2. Time began.
3. Time ended.
4. Duration.
5. Snowfall measurements — if year-round station.

Kind of Precipitation

The kind of precipitation refers to whether

it was drizzle, rain, snow, sleet, or hail. This information is often entered in coded form on the record sheet.

Time Began and Ended

The beginning and ending time of each continuous precipitation occurrence should be recorded, usually to the nearest hour. A recording rain gage is a ready source for this type of information.

Duration

The duration of precipitation refers to the elapsed time from beginning to end of each occurrence. Usually the sum of the elapsed times for all occurrences during the reporting period is entered.

Snowfall Measurements

Snowfall is the amount of new snow that has fallen during the recording interval (usually 24 hours). Measurements normally required are snow depth and water equivalent. Often the total accumulated depth is also desired. This total depth is sometimes obtained by simply reading the depth against a snow stake (fig. 4.2).

If snowfall is being measured for official climatological records or for special studies, procedures that are more detailed than those discussed here will be required. The National Weather Service provides such detailed procedures (U.S. Department of Commerce, ESSA 1970).

Snowfall is the depth of the new snow measured in inches and tenths of inches. Water equivalent is the water content of the new snow that is measured in inches and tenths of inches in the same way that rain is measured.

The standard 8-inch rain gage, from which collector and measuring tube have been removed, can be used to measure both depth of new snow and water equivalent. This method should be used only where a high degree of accuracy is **not** required. Wind can have a significant effect on the amount of snow caught by the gage as well as the level of the snow in the gage. When accumulated snow depths are greater than the height of the rain gage, or when a higher degree of accuracy is desired, a snowboard should be used.

The snowboard is a wooden or plastic board about 4 feet square. It should be mounted level, either on or close to the ground in a protected opening. One-half of the board is cleared after each snowfall, the other half is left undisturbed. The depth and water equivalent of the new snow, as well as the total depth of the accumulated snow (old and new), are measured.

Like other methods of snow measurement, this method is wind sensitive. Every effort should be made to locate the snowboard in an area that obtains representative snowfall but is sheltered from the wind. If wind is allowed to blow across the snowboard, part of the old snow on the board could blow or drift onto the other half.

CROSS REFERENCE: Installation and Exposure 8.9; Operation 13.1, 13.4.

CHAPTER 5

FUEL MOISTURE

Since Gisborne (1933) first developed the idea in 1924, fuel moisture indicator sticks, or similar types of analogs, have been widely used to estimate the moisture content of small forest fuels.

5.1 FUEL MOISTURE STICKS

A fuel moisture indicator stick is ". . . a specially prepared stick or set of sticks of known dry weight continuously exposed to the weather and periodically weighed to determine changes in moisture content as an indication of moisture change in forest fuels" (Society of American Foresters 1958). Unlike conventional weather instruments, indicator sticks do not measure any single weather variable but rather they ". . . measure the net effect of climatic factors affecting flammability in terms of the most significant item, the fuel itself." (Davis 1959). For this reason, the practice of using fuel moisture indicator sticks, or some other analog of fuel moisture, is common at fire-weather stations, both in conjunction with fire rating systems and prescribed burning operations.

A standard fuel moisture indicator stick consists of four 1/2-inch ponderosa pine sapwood dowels spaced one-fourth inch apart on two 3/16-inch-diameter hardwood pins. The dowels are held in place on the pins by wire brads at each intersection. The resultant indicator stick (fig. 5.1) is 2¾ inches wide, about 20 inches long, and has an ovendry weight of 100 grams. A screw hook inserted in the end of one of the dowels and the notation, "This end NORTH, this side up" is stamped just below the screw hook in the surface of the dowel (Hardy 1953).

CROSS REFERENCE: Installation and Exposure 8.10; Operation 15; Maintenance 23.

5.2 INORGANIC FUEL MOISTURE ANALOG

The wooden fuel moisture stick has several important shortcomings as an analog of fuel moisture.[2]

[2]*Michael A. Fosberg. Analogs for fuel moisture determination in National Fire Danger Rating. Unpublished report on file at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521. Office Report 2106-5, September 2, 1971.*

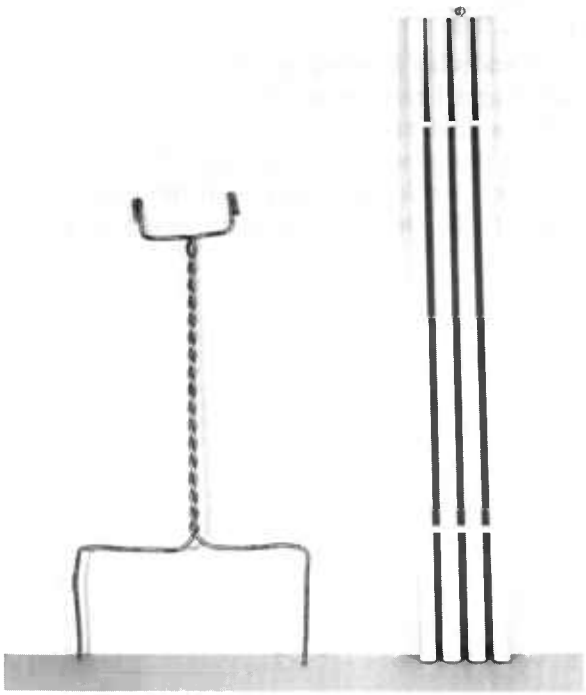


Figure 5.1. — One-half-inch ponderosa pine fuel moisture indicator sticks and wire mounting rack (two required per installation).

1. The response characteristics of wood are highly variable. Dowels cut from the same board will often give different fuel moisture values when exposed side by side in the same environment.

2. Exposure and aging can change both the response characteristics and the calibration of a wooden stick. Discoloration with age changes the radiation characteristics of the stick. If the dowels check and split as they often will, more surface area is exposed to the air and the calibration of the stick is changed. The actual weight or mass of the stick can be reduced if splitting and checking are severe.

Work currently in progress will produce an analog made of an inorganic substance which will overcome the deficiencies of the wooden fuel moisture stick. The final product will have the following attributes:

1. It will be reproducible. Each analog will respond exactly the same as all others.

2. It will be constructed to respond in a manner similar to dead forest fuels.

3. Analogs of different size and shape will be produced so that other than fine dead fuels can be evaluated.

4. Electric readout will be provided so that values can be obtained at a glance from an attached dial or chart record.

When development is completed and they become generally available, the inorganic fuel moisture analog will replace the fuel moisture stick at fire-weather stations.

5.3 FUEL MOISTURE SCALES

The weight, in excess of ovendry weight (100 grams for a 1/2-inch ponderosa pine stick) of a properly exposed analog represents fuel moisture. Fuel moisture analogs can be measured, therefore, by weighing them on a suitable scale. Several such scales in common use are: the Appalachian scale; the Chisholm type portable scale; and the Williams pocket scale. All of these scales were developed specifically to weigh fuel moisture indicator sticks. Standard laboratory balances, especially the triple beam balance and the Harvard balance, are also used to weigh fuel moisture sticks.

The Appalachian Fuel Moisture Scale

The Appalachian fuel moisture scale is preferred over two-pan (Harvard balance) and triple beam balances for obtaining fuel moisture stick weights (fig. 5.2) at fire-weather stations. Byram (1940) designed the Appalachian scale specifically for measurement of basswood slats, which were similar in purpose to fuel sticks but had variable ovendry weights. It consists of a pivoted balance arm mounted on a 10-by 10-inch metal back. A sliding weight on the arm is used to adjust the scale for the ovendry weight of the analog. The stick, or other analog, is hung on a small hook at the left end of the balance arm when weighed. The pointed right end of the balance arm indicates the moisture content of the analog on a curved scale graduated from 0 to 50 percent. A standard 100-gram weight is provided to level and zero the scale.

The Appalachian scale shelter (Barney 1962) was designed to insure correct leveling of the scale and facilitate the weighing of fuel moisture sticks. It provides for adjustment in two planes, adequate room inside, and ample viewing through a large window in the door (fig. 5.2).

CROSS REFERENCE: Installation and Exposure 8.11; Operation 15.1; Maintenance 24.1.

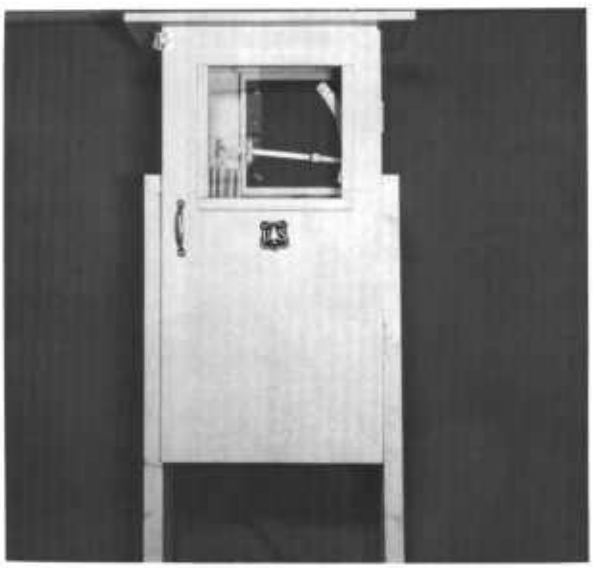


Figure 5.2. — Appalachian fuel moisture scale mounted in Appalachian scale shelter.

Chisholm Portable Fuel Moisture Scale

This scale works in the same manner as the Appalachian scale except that it has no adjustment for a range of ovendry weights. It is calibrated to use the 100-gram, ovendry weight, 1/2-inch stick (fig. 5.3). Although it can be hand held, it is much easier to use if it can be hung on a post, tree, truck, or similar support. A 100-gram test weight is provided with the scale.

CROSS REFERENCE: Operation 15.2; Maintenance 24.4.

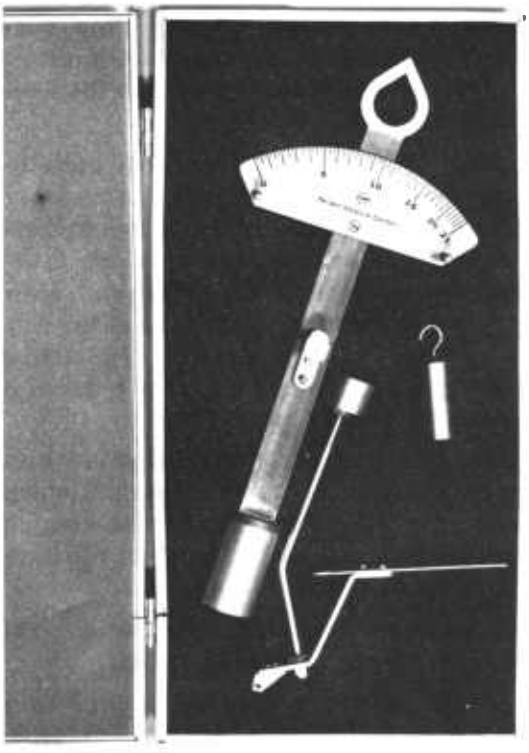


Figure 5.3. — Portable fuel moisture scale.

Williams Pocket Firestick Moisture Scale

This is a very portable, accurate, and durable scale (fig. 5.4). It is 1½ inches in diameter and less than 5 inches long. It weighs 14 ounces. The case weighs 100 grams and doubles as a calibration weight. The graduations are read in direct percentage of the amount of moisture in 100 grams of wood. The scale is sensitive to one-fourth gram. Micrometer graduations are read up to 25 percent.

CROSS REFERENCE: Operation 15.3; Maintenance 24.3.

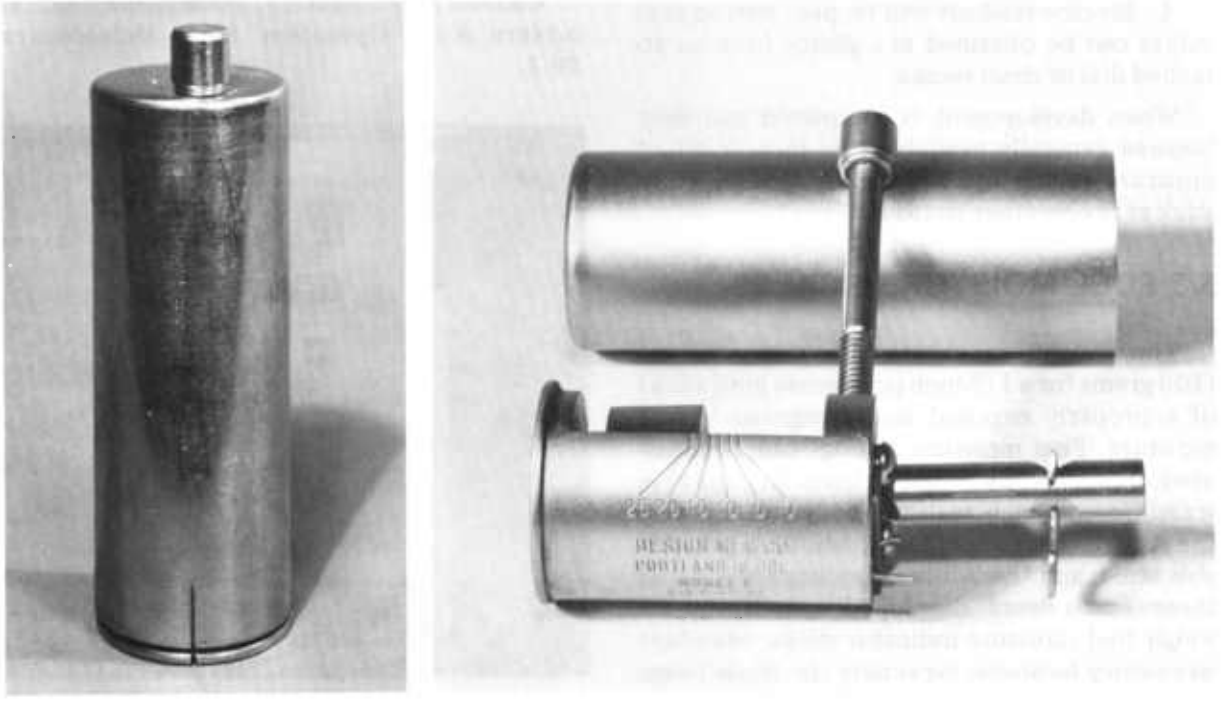


Figure 5.4. — Portable firestick moisture scale: *Left*, Assembled for storage; *right*, assembled for use.

Figure 5.5. — Three models of the triple beam balance.

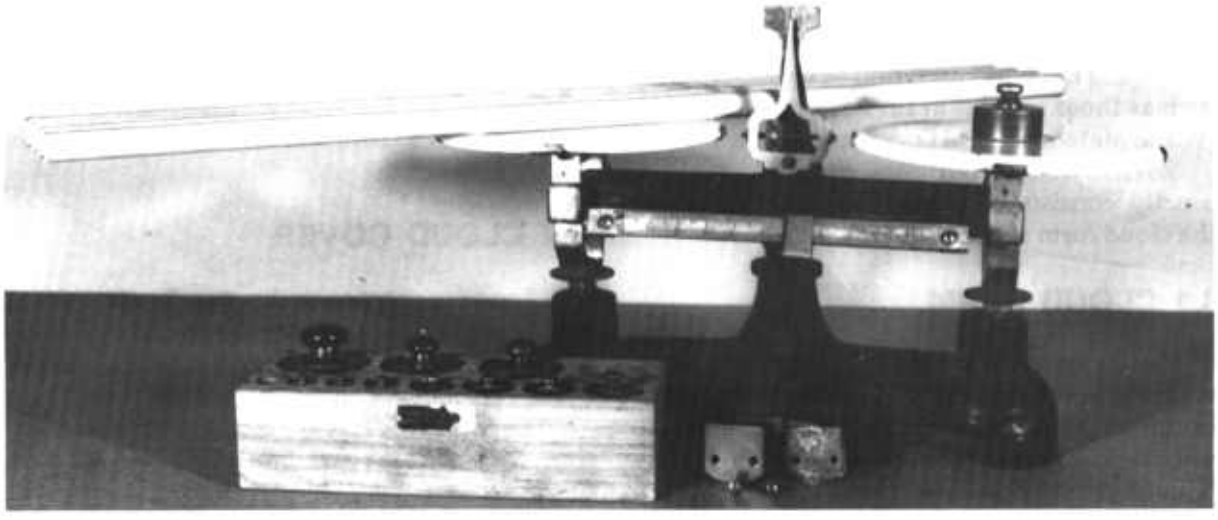


Figure 5.6. — The Harvard balance.

Triple Beam and Harvard Balances

These are standard laboratory balances. The triple beam balance has a single pan (fig. 5.5) and the Harvard balance a double pan (fig. 5.6). Fuel stick weight is read from the scales after balance has been achieved.

When used at fire-weather stations, triple beam and Harvard balances are installed in a scale shelter similar to that shown in figure 5.7. It is important that the shelter be watertight, firmly mounted, and exactly level and plumb.

CROSS REFERENCE: Installation and Exposure 8.11; Operation 15.4; 15.5; Maintenance 24.5, 24.6.

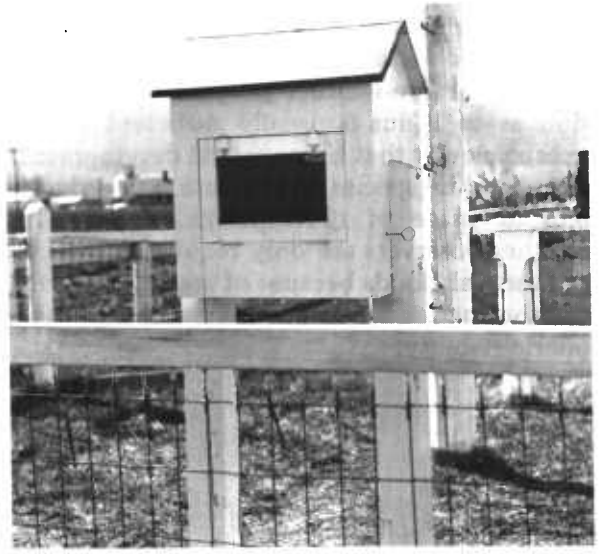
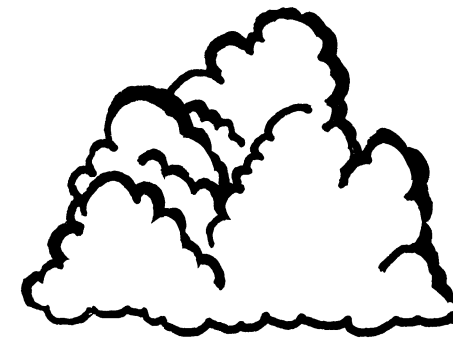


Figure 5.7. — Scale shelter for triple beam balance or Harvard balance.

CHAPTER 6

CLOUDS



A cloud is a visible aggregate of minute particles of water or ice, or both, in the free air. This aggregate may include larger particles of water and ice and nonaqueous liquid or solid particles, such as those present in fumes, smoke, or dust (World Meteorological Organization 1956).

For fire-weather purposes, cloud observation usually consists of identifying and recording the cloud form and amount of cloud cover.

6.1 CLOUD FORM

Clouds are constantly changing, hence they exhibit an endless variety of forms. For classification purposes, however, only a few characteristic cloud forms are recognized. The "International System" for cloud classification lists 10 major cloud forms (genera) within three height classes (families). Several species are recognized within each genus. The system provides for further breakdown of cloud forms (varieties, supplementary features, etc.) but these are rarely needed for fire-weather purposes. Identification as to genus is usually sufficient for all except clouds that have vertical development. These require species identification in order to indicate stage of development. Often, fire-weather observers are only required to record the vertical clouds because of their importance as lightning producers and indicators of atmospheric stability.

A simplified cloud classification for fire-weather purposes is presented in table 6.1. Characteristic cloud forms are illustrated in figure 6.1. Observers are urged to obtain current editions of the National Weather Service Cloud Form charts to supplement the illustrations in figure 6.1.

6.2 CLOUD COVER

Cloud cover refers to the amount (in tenths) of the sky which is covered by clouds or hidden by surface-based obscuring phenomena such as smoke or fog.

The following average cloud cover classification is sufficient for most fire-weather purposes:

Clear. — Sky is cloudless or the cloud cover averages less than one-tenth (to the nearest tenth).

Scattered clouds. — An average of one-tenth through five-tenths of the sky is covered with clouds.

Broken clouds. — An average of six-tenths through nine-tenths of the sky is covered by clouds.

Overcast. — An average of more than nine-tenths of the sky is covered by clouds.

Obscured. — Sky is completely hidden by surface-based obscuring phenomena such as fog, smoke, smog, or overcast.

Table 6.1. — *A simplified cloud classification for fire-weather purposes*

Family	Genus	Species	Abbreviation	Description
HIGH CLOUDS 16,500 to 45,000 feet	Cirrus		Ci	Wispy, hair-like clouds. Formed of delicate filaments, patches, narrow bands, or feather-like plumes.
	Cirrocumulus		Cc	Thin, white, grainy, and rippled patches or sheets or layers. Show very slight vertical development in the form of turrets and shallow towers.
	Cirrostratus		Cs	Transparent, hair-like or smooth whitish veil. Covers all or part of the sky. Produces halo phenomenon.
MIDDLE CLOUDS 6,500 to 23,000 feet	Altocumulus		Ac	Extensive sheet of regularly arranged white and gray, somewhat rounded cloudlets.
		Altocumulus castellanus	Ac cas	Altocumulus with vertical development in the form of small towers or turrets. Elements have a common horizontal base and appear to be arranged in lines.
		Altocumulus lenticularis	Ac len	A patch of altocumulus in the shape of a lens or almond. Often stationary and very elongated with well-defined outlines.
	Altostratus		As	Grayish or bluish sheet or layer covering all or part of the sky. Sun may show vaguely but no halo.
	Nimbostratus		Ns	Dark, gray cloud layer thick enough to blot out the sun. Continuous rain or snow; without lightning.
LOW CLOUDS Surface to 6,500 feet	Stratocumulus		Sc	Gray and whitish layer with dark patches formed of nonfibrous rounded masses or rolls. Like altocumulus but lower. May have virga at base.
	Stratus		St	Gray layer with uniform base which may give drizzle. When sun is visible through cloud, its outline is clearly discernible.
THE VERTICAL CLOUDS	Cumulus		Cu	Detached clouds, generally dense and sharply outlined. Developing vertically in the form of rising mounds, domes, or towers. Brilliant white in sunlight. Base is dark and nearly horizontal.
		Cumulus humilis	Cu hum	*Fair weather cumulus* with little vertical extent; generally appear flattened.
		Cumulus congestus	Cu con	*Towering cumulus* with strong vertical extent in the form of domes or towers. May be accompanied by other cumulus or stratocumulus with bases at same level.
	Cumulonimbus		Cb	Heavy and dense cloud with considerable vertical extent, in the form of a mountain or huge towers. The upper part usually smooth, sometimes fibrous, with top flattened to anvil shape or vast cirrus plume. Produces lightning, hail, tornadoes, heavy rain, and high winds.
		Cumulonimbus calvus	Cb cal	*Cumulonimbus without anvil.* Any tower development lacks sharp outlines. May have rain or virga at base.
		Cumulonimbus capillatus	Cb cap	*Cumulonimbus with anvil-shaped top.* Top may also be in the form of a plume, or a vast more or less disorderly mass of hair. Top may extend to 40,000 feet or more. May have rain or virga at base. Produces lightning, hail, heavy rain, and high winds.

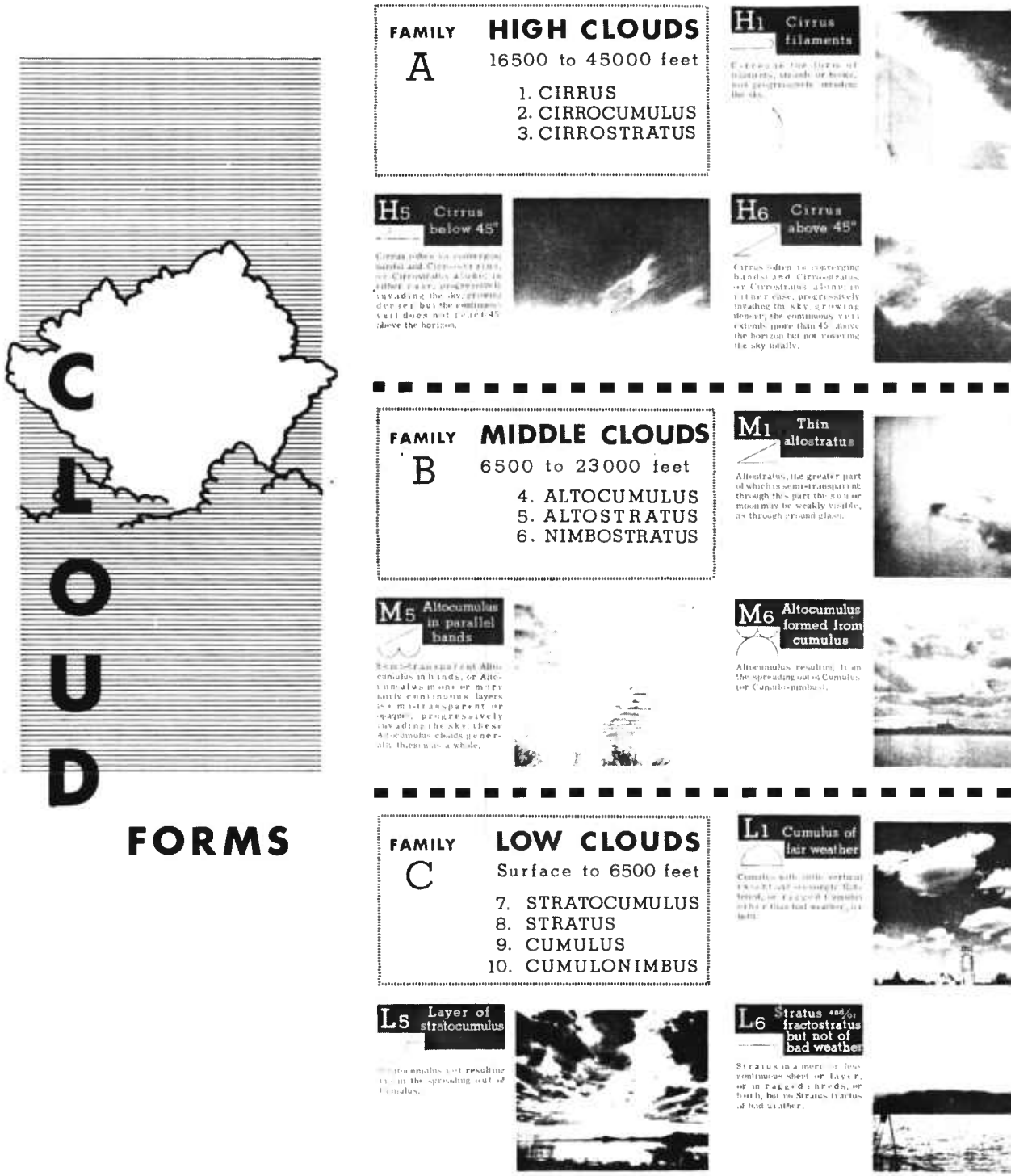


Figure 6.1. — Characteristic cloud forms. (U.S. Department of Commerce, Weather Bureau "Cloud Forms" Revised May 1962).

H2 Dense cirrus patches

Dense Cirrus, in patches or tangled sheaves, usually not increasing and possibly the remains of the upper part of a Cumulo-nimbus; or Cirrus with sproutings in the form of small turrets, or Cirrus in the form of tufts.

H3 Dense cirrus from cumulonimbus

Dense Cirrus, often in the form of an anvil, being the remains of the upper parts Cumulonimbus.

H4 Cirrus with hooks or tufts

Cirrus in the form of hooks or filaments, or both, progressively invading the sky; they generally become denser as a whole.

H7 Cirrostratus covering the whole sky

Veil of Cirrostratus covering the celestial dome. The presence of the halo implies an abundance of ice crystals and this phenomenon is useful in distinguishing cirrus clouds from haze aloft.

H8 Cirrostratus not covering the whole sky

Cirrostratus not progressively invading the sky and not completely covering the celestial dome.

H9 Cirrocumulus

Cirrocumulus alone; or Cirrocumulus accompanied by Cirrus or Cirrostratus, or both, but Cirrocumulus is predominant.

M2 Thick altostratus

Altostratus, the greater part of which is sufficiently dense to hide the sun or moon, or Nimbostratus.

M3 Thin altocumulus

Altocumulus, the greater part of which is semi-transparent, the various elements of the cloud change only slowly and are all at a single level.

M4 Altocumulus in patches

Patches often in the form of almonds or fishes of Altocumulus, the great part of which is semi-transparent; the clouds occur at one or more levels and the elements are continually changing in appearance.

M7 Altocumulus in two or more layers

Altocumulus in two or more layers, usually opaque in places, and not progressively invading the sky; or opaque layer of Altocumulus not progressively invading the sky; or Altocumulus together with Altostratus or Nimbostratus.

M8 Castellated altocumulus

Altocumulus with sproutings in the form of small towers or battlements, or Altocumulus having the appearance of cumuliform tufts.

M9 Altocumulus of chaotic sky

Altocumulus of chaotic sky, generally at several levels.

L2 Large towering cumulus

Cumulus of moderate or strong vertical extent, generally with protuberances in the form of domes or towers, either accompanied or not by other Cumulus or by Strato-cumulus, all having their bases at the same level.

L3 Cumulonimbus without anvil

Cumulonimbus, the summits of which, at least partially, lack sharp outlines, but are neither clearly fibrous (cirriform) nor in the form of an anvil; Cumulus, Stratocumulus or Stratus may also be present.

L4 Stratocumulus formed from cumulus

Stratocumulus formed by the spreading out of Cumulus; Cumulus may also be present.

L7 Low clouds of bad weather

Stratus fractus of bad weather or Cumulus fractus of bad weather, or both (pannus), usually below Altostratus or Nimbostratus.

L8 Cumulus and stratocumulus

Cumulus and Stratocumulus other than that formed from the spreading out of Cumulus; the base of the Cumulus is at a different level from that of the Stratocumulus.

L9 Cumulonimbus with anvil top

Cumulonimbus, the upper part of which is clearly fibrous (cirriform), often in the form of an anvil, either accompanied or not by Cumulonimbus without anvil or fibrous upper part, by Cumulus, Stratocumulus, Stratus or pannus.

PART 2. THE FIRE-WEATHER STATION

There are several sets of standards that may logically be applied to fire-weather stations. One set of standards covers the location of the station, the measurements taken, and the instruments used from the standpoint of data comparability. These standards apply primarily to networks of permanent stations such as those maintained for climatological and fire-danger rating purposes. The objectives of these standards are to assure that: (1) data collected at any given time at one station are comparable to similar data collected at the same time at all other stations in the network; and (2) data collected at a particular station at any given time are comparable to previous data collected at the same station.

A second set, which applies to all stations, has to do with the location and arrangement of the station with regard to installation and exposure requirements of the instruments involved. The objective of such standards is to insure the collection of accurate data that effectively samples the weather prevailing over the specific station area.

The term "standard fire-weather station" as used in this handbook refers primarily to the permanent type of station that is part of a weather collection system or network. Such networks are maintained for fire-weather forecasting and to obtain fire-danger ratings. Many of these network stations also serve as National Weather Service climatological stations. Both sets of standards described above apply to these standard fire-weather stations.

There is a third set of standards that applies to station networks. These are the administrative standards which prescribe observation time, method of recording data, precision of readings, etc. The items vary according to the purpose for which the station is maintained and are not covered in detail in this handbook. They are, nonetheless, important considerations for data comparability. A fire-weather observer should become thoroughly familiar with all the administrative standards that apply to his station.

In the following pages, guidelines for the location and layout of the standard fire-weather station are provided, equipment needs are listed, and installation and exposure requirements of the recommended instruments are detailed.

A fire-weather station condition report that summarizes the standards presented in this part of the handbook is included in the Appendix.

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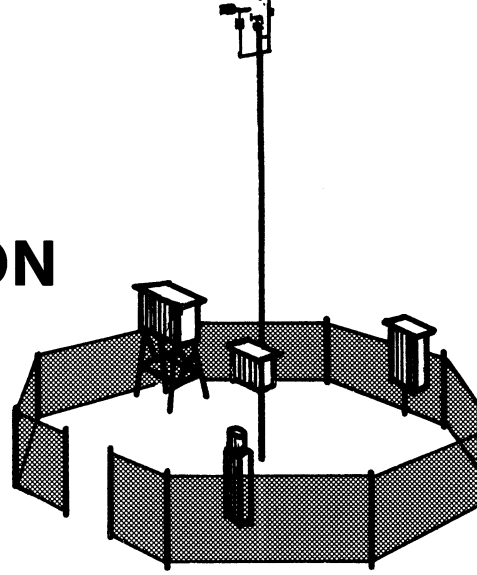
CHAPTER 7

THE STANDARD FIRE-WEATHER STATION



7.1 LOCATION

The standard fire-weather station should be located in a large opening, away from obstructions and sources of dust and surface moisture. The station should be on level ground where there is only a low vegetative cover. Furthermore, it should be situated to receive full sun for the greatest possible number of hours per day during the fire season. If located on a slope, a south or west exposure is required to meet fire-danger rating standards (Deeming, Lancaster, Fosberg, and others 1972).

The following rules should govern the location of a standard fire-weather station:

1. **Locate the station in a place that is representative of the conditions existing in the general area of concern.** Consider vegetative cover type, topographic features, elevation, climate, local weather patterns, etc.

2. **Select a site that will provide for long-term operation and a relatively unchanged exposure.** Consider site development plans, e.g., roads, buildings, parking areas; ultimate obscuration by growth of vegetation; observer availability; etc.

3. **Arrange the station so as to give data that are representative of the specific area in which the station is situated.** Consider exposure requirements for each instrument in relation to such things as prevailing wind, movement of the sun, topography and vegetative cover, nearby reflection surfaces, and wind obstructions.

In accordance with the above rules, the following situations should be **avoided** when selecting a station site:

1. **Sources of dust** such as roads and parking areas. If unavoidable, locate station **at least** 100 feet on the windward side of the source.

2. **Sources of surface moisture** such as irrigated lawns, pastures and gardens, lakes, swamps, and rivers. If unavoidable, locate station several hundred feet to the **windward** side of the source.

3. **Large reflective surfaces** such as white painted buildings. If unavoidable, locate station on north side but far enough away so as not to be artificially shaded; **at least** a distance equal to the height of the reflective surface or 50 feet, whichever is greater.

4. **Extensive paved or black-topped areas.** If unavoidable, locate station **at least** 50 feet to windward.

5. **Large buildings, trees, and dense vegetation.** Locate station **at least** a distance equal to the height of the obstruction.

6. **Distinct changes in topography** such as hummocks, gullies, peaks, ridges, steep slopes, and narrow valleys.

7.2 EQUIPMENT LIST

The standard fire-weather station should contain the following equipment:

1. Cotton region instrument shelter including the support.
2. Standard maximum-minimum thermometers including a Townsend Support.
3. Electric fan psychrometer.
4. Contacting anemometer equipped with 1/60-mile contacts and pole mount.

5. Mechanical wind counter equipped with a timer.

6. Standard 8-inch rain gage including the support.

7. Wind direction system — including the vane and remote readout.

Highly desirable, especially for fire management and climatological purposes, are:

1. Hygrothermograph.
2. Recording rain gage.

In addition to the above, these items may be required for fire-danger rating purposes:

1. Fuel moisture sticks or other fuel moisture analog.
2. Fuel moisture scale or other analog readout device mounted in protective shelter.

7.3 LAYOUT

Arrangement of Equipment

A recommended ground plan for a standard fire-weather station is shown in figure 7.1. This particular arrangement of equipment affords a free flow of air and full exposure to available sunlight. Station size should be based on the individual situation. Ideally, the size should be large enough to accommodate additional instruments as they become necessary. An area 15 feet by 15 feet should, however, be considered a minimum size for proper exposure of minimum instrumentation.

Grounds

The station grounds should be free of tall vegetation. Brush and trees should also be kept down within a 20-foot radius of the station. A native perennial grass ground cover is ideal provided it is kept well clipped (about 4 inches) and is not watered. Graveled paths to the various instrument locations are desirable since they will not become dusty during dry weather or muddy during rainy weather.

Fence

A fence around the station site is not essential unless there is danger of instruments being upset or otherwise damaged by animals or curious people. However, a fence often improves the appearance of the station and tends to discourage tampering by unauthorized personnel.

If a fence is installed, it should be no more that 4 feet high and constructed of open type material such as woven wire. A picket fence, for example, is unacceptable since it would restrict the free flow of air across the enclosure.

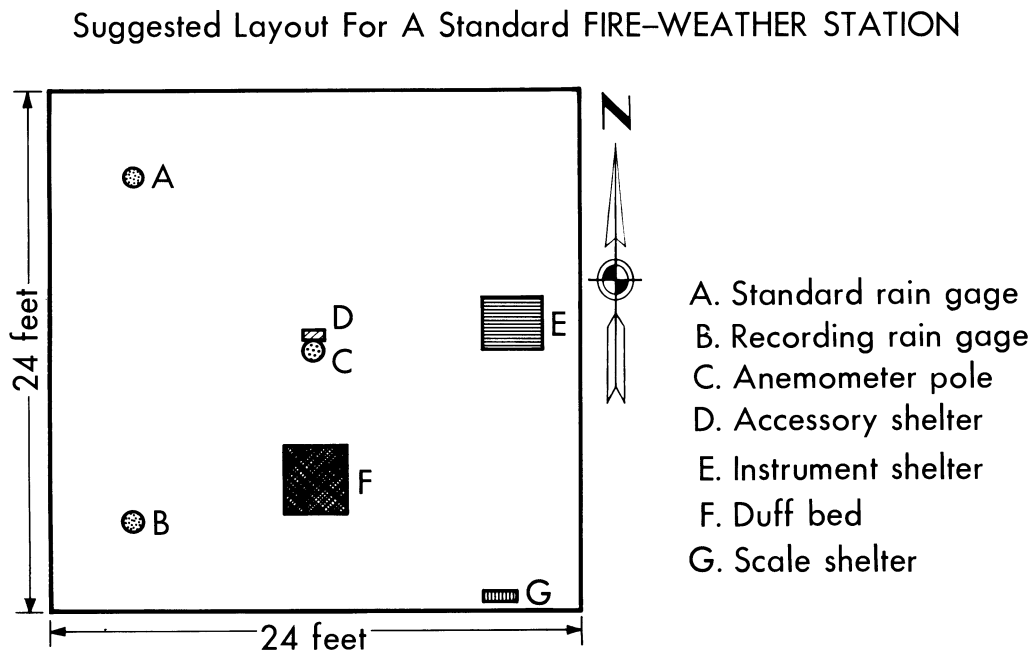


Figure 7.1. — Ground plan for a standard fire-weather station.

CHAPTER 8

INSTALLATION AND EXPOSURE OF INSTRUMENTS

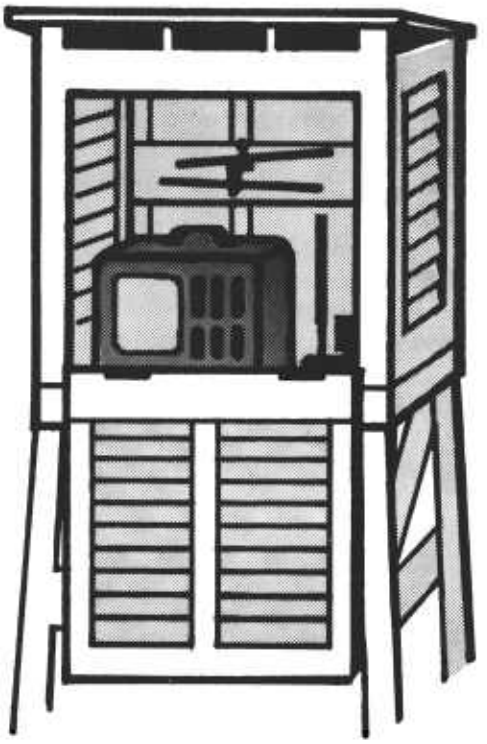


Figure 8.1. — Instrument shelter mounting pin. (See Appendix for detail drawings.)

8.1 INSTRUMENT SHELTER

A properly installed instrument shelter will meet the following requirements:

1. Open to the free movement of air.
2. Positioned over a low vegetative cover.[3]
3. North-facing door.
4. Shelter floor 4 feet above ground.
5. Shelter floor level and plumb.
6. Shelter firmly secured to stand.
7. Stand firmly secured to ground.

At a permanent fire-weather station, it is advisable to fasten the legs of the shelter stand to concrete footings or to metal or treated wood stakes. Burying the legs of the stand is not recommended for several reasons: the buried portion of wooden stands will rot, and burying the legs of a 4-foot-high stand will result in the shelter floor being less than 4 feet above the ground. Metal mounting pins of the type shown in figure 8.1 can aid proper instrument shelter installation in many situations. These pins are easy to install and can aid in obtaining a level mounting for the shelter (fig. 8.2).

Remember, the instrument shelter is a screen for temperature-sensitive instruments. It is not a storeroom, or even a place for other instruments (fig. 8.3).

[3] If vegetation is absent and cannot be established, use a 2-inch bed of forest litter or small, washed, gravel.

Figure 8.2. — Installing and leveling instrument shelter using mounting pins.

8.2 STANDARD MAXIMUM-MINIMUM THERMOMETER

The standard maximum-minimum thermometer equipped with a Townsend Support is designed to be exposed in an instrument shelter.

Townsend Support

Fasten the Townsend Support at the center of the instrument shelter cross board. Make sure the Support is properly oriented so that the spinning clamp is on the bottom (fig. 8.3).

Maximum Thermometer

Mount the maximum thermometer in the spinning (lower) clamp of the Townsend Support about two-thirds of the way up the stem from the bulb (near the 80° mark on a -20° to 120° F. scale thermometer). If mounted too near the middle, the mercury column might separate when whirled and part of it may become lodged at the top of the stem.

Tighten the thumbscrew on the clamp securely to prevent the thermometer from being thrown out when whirled. When properly mounted, the bulb end of the maximum thermometer is on the left and raised about 5° above the horizontal. This position facilitates the flow of mercury as temperature rises and minimizes the chance of mercury retreating through the constriction as temperature drops.

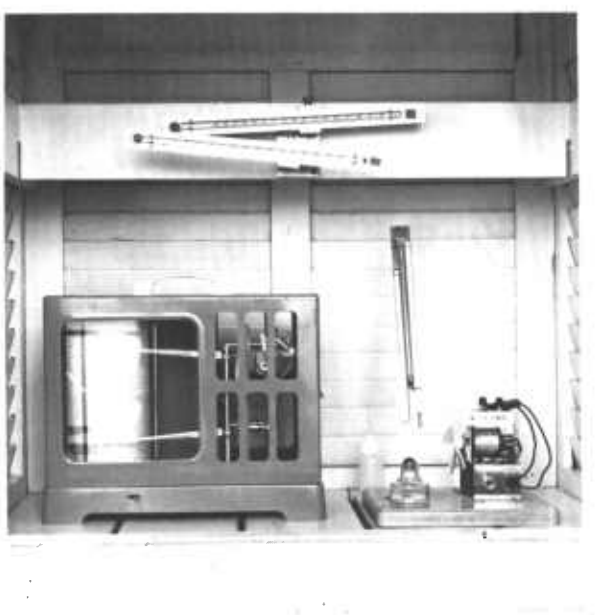


Figure 8.3. — Suggested arrangement of instruments in a cotton region shelter. Notice that only temperature-sensitive instruments are installed in this shelter.

Minimum Thermometer

Mount the minimum thermometer in the upper clamp, just slightly beyond the middle of the stem (near the 40° mark on a −60° to 100° F. scale thermometer).

Tighten the thumbscrew on the clamp to hold the thermometer in place. When properly mounted, the bulb end of the minimum thermometer is on the left and roughly 5° below the horizontal. This position facilitates the downward movement of the index when temperature drops and minimizes the chance of the index rising as temperature rises. It also tends to prevent accumulation of vaporized liquid above the column or resulting bubble formation.

CROSS REFERENCE: Description 1.1; Operation 10.1; Maintenance 16.

8.3 ELECTRIC FAN PSYCHROMETER

Locate the psychrometer in the right front portion of the instrument shelter and fasten to the floor board (fig. 8.3). Make sure that the installation of the psychrometer does not interfere with the whirling of the maximum thermometer. Observe the polarity of the battery wires when connecting the fan to the battery. Insufficient ventilation of the wet bulb will occur if wires are switched.

CROSS REFERENCE: Description 2.2; Operation 11.1-11.2; Maintenance 17.1-17.4.

8.4 HYGROTHERMOGRAPH

Set the hygrothermograph in the left front portion of the instrument shelter (fig. 8.3). Make sure it is placed far enough forward so it does not interfere with the whirling of the maximum thermometer.

CROSS REFERENCE: Description 2.3; Operation 12; Maintenance 18.

Figure 8.4. — A standard anemometer installation 20 feet above open, level ground.

8.5 ANEMOMETER

The anemometer should be exposed 20 feet above open, level ground (fig. 8.4). This standard height must be adjusted to compensate for height of ground cover, uneven ground, and nearby obstructions. The anemometer does not need to be at the weather station enclosure. It can be one-fourth mile or more away if necessary to sample adequate air movement representative of the geographic area of concern.

Height Adjustment

Uneven Ground

In rolling country or rough ground characterized by depressions and ridges, mount the anemometer 20 feet over a representative high spot. If mounted over a low spot, increase the height by the average depth of the depression in relation to the surrounding high ground.

Ground Cover

Adjustment of anemometer height will depend on the density and height of the ground cover. If the ground is densely covered with rocks, brush, or small trees, increase the height of the anemometer by the average height of the ground cover.

If the ground cover is scattered, increase the height of the anemometer by one-half the average height of the ground cover.

If the ground cover is sparse, increase the height of the anemometer by one-third the height of the ground cover.

Nearby Obstacles

No adjustment of anemometer height is necessary if an obstacle is more than seven times its own height away from the anemometer.

If the distance between the anemometer and an obstacle is less than seven times the

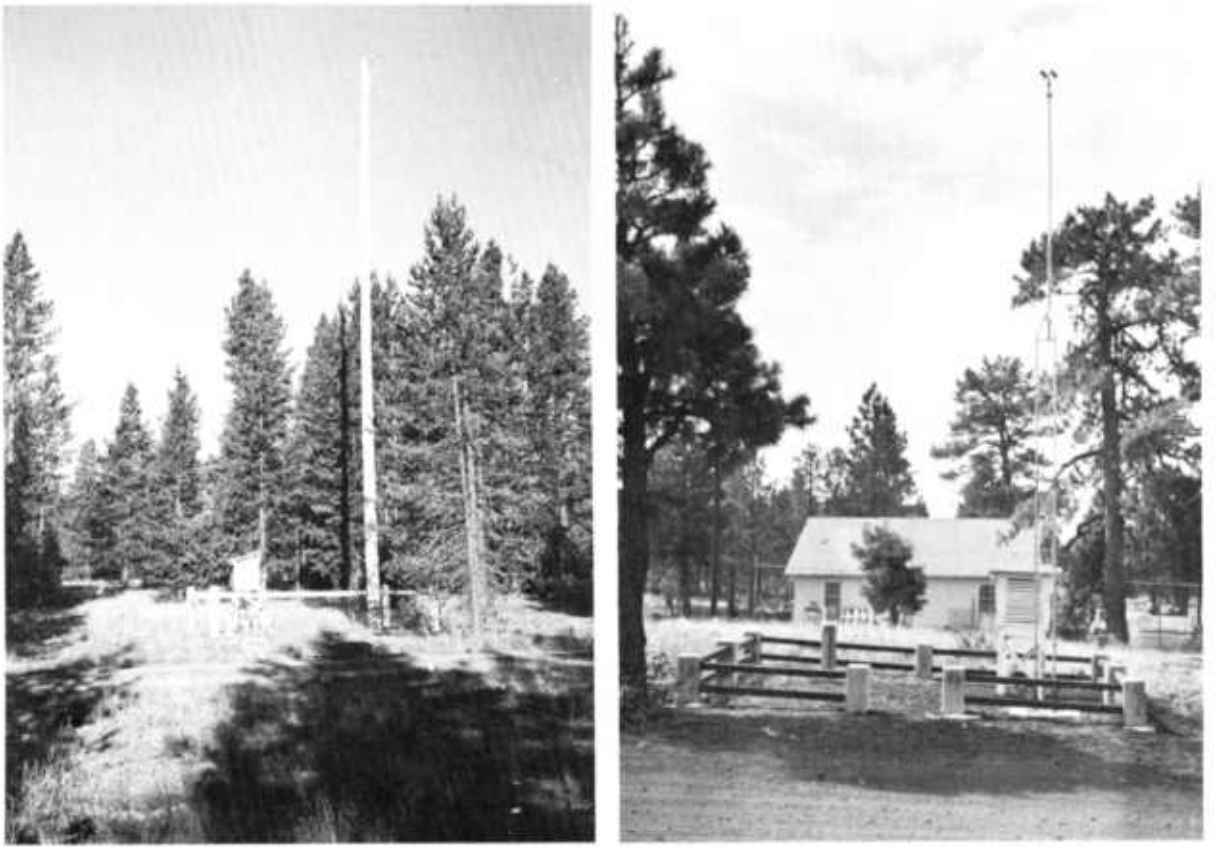


Figure 8.5. — In these installations the anemometer height is adjusted upwards because of nearby trees.

height of the obstacle (fig. 8.5), table 8.1 can be used to determine the adjusted anemometer height (USDA Forest Service 1964b).

Installation

Although mounting the anemometer on a wood pole is the most common type of installation of fire-weather stations, iron pipe poles are much in evidence (figs. 3.1, 8.4, 8.5, 8.6, and 8.7).

Metal towers (fig. 8.5) are being used more often, especially where anemometer heights in excess of 25-30 feet are required and where portability is a major consideration in establishing temporary field stations. Metal towers are available in a variety of forms: (1) one-piece towers of a specified height; (2) stacked 10-foot sections that are extended and bolted together; (3) telescoping sections that crank up and down; and (4) foldover models equipped with a winch-hand crank for raising and lowering the upper half of the tower.

Regardless of the type used, the installations should accomplish the following: (1) be wind-firm; (2) allow easy access to the anemometer; (3) accommodate attachment of the readout device; (4) provide for periodic adjustment of anemometer height; and (5) be compatible with any existing lightning protection system. These rules apply to temporary field installations (fig. 8.7) as well as to permanent fire-weather station installations.

Lightning Protection

In many areas, good safety practice requires adequate lightning protection on the anemometer as well as on the wires leading to the readout device that is located inside a lookout tower or nearby building.

Lookout Tower Installation

If the anemometer is mounted on a lookout tower (fig. 8.8) follow these procedures:

Table 8.1. — *Anemometer height (20-foot standard)*[1] *correction table*

Distance to obstacle	Height of obstacle														
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Feet	---------- [2]*Feet* ----------														
10	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	25	34	--	--	--	--	--	--	--	--	--	--	--	--	--
30	24	32	41	--	--	--	--	--	--	--	--	--	--	--	--
40	22	30	39	48	--	--	--	--	--	--	--	--	--	--	--
50	21	29	37	46	55	--	--	--	--	--	--	--	--	--	--
60	21	27	35	44	53	62	--	--	--	--	--	--	--	--	--
70	20	26	34	42	51	60	69	--	--	--	--	--	--	--	--
80	20	24	32	40	49	58	67	76	--	--	--	--	--	--	--
90	20	23	31	38	47	56	65	74	83	--	--	--	--	--	--
100	20	22	29	37	45	54	63	72	81	90	--	--	--	--	--
120	20	21	26	34	42	50	59	68	77	86	95	104	--	--	--
140	20	20	24	31	39	47	55	64	73	82	92	100	109	118	--
160	20	20	23	28	36	44	52	60	69	78	87	96	105	114	123
180	20	20	22	26	33	41	49	57	65	74	83	92	101	110	119
200	20	20	20	24	30	38	46	54	62	70	79	88	97	106	115
220	20	20	20	23	28	35	43	51	59	67	75	84	93	103	112
240	20	20	20	22	26	32	40	48	56	64	72	80	89	98	107
260	20	20	20	21	25	30	37	45	53	61	69	77	85	94	103
280	20	20	20	20	24	28	34	42	50	58	66	74	82	90	99
300	20	20	20	20	23	26	32	39	47	55	63	71	79	87	95
350	20	20	20	20	20	23	27	33	39	48	55	64	71	80	88
400	20	20	20	20	20	21	25	28	34	40	48	56	64	72	80
450	20	20	20	20	20	20	22	26	29	35	41	48	56	65	73
500	20	20	20	20	20	20	20	23	27	30	36	42	49	56	65
600	20	20	20	20	20	20	20	20	21	25	28	32	38	44	50
700	20	20	20	20	20	20	20	20	20	20	23	27	31	34	40
800	20	20	20	20	20	20	20	20	20	20	20	22	26	29	33
900	20	20	20	20	20	20	20	20	20	20	20	20	20	24	28
1,000	20	20	20	20	20	20	20	20	20	20	20	20	20	20	22
1,100	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

[1] *The computed anemometer heights do not include an adjustment for uneven ground or ground cover. These adjustments must be added to table values.*

[2] *For distances less than height of obstruction, place anemometer 20 feet above the obstruction.*

1. Clamp a piece of #2 copper conductor onto the anemometer pole (if pipe) or the anemometer itself (if pole is wood).

2. Run the conductor underneath the catwalk of the lookout tower cab and clamp it to the existing lightning protection system.

3. Install a carbon block lightning arrester (#402-RR, or equivalent) on the tower leg. The wire connecting the anemometer to the readout device must first go through this arrester; then the wire can be run into the tower cab. Furthermore, this wire must be solidly connected to both the anemometer pole and the tower.

Figure 8.6. — This anemometer installation allows easy access to the anemometer and provides for periodic height adjustment. The wire on the right of the pole connects the anemometer to a wind counter located in the fire dispatcher's office.

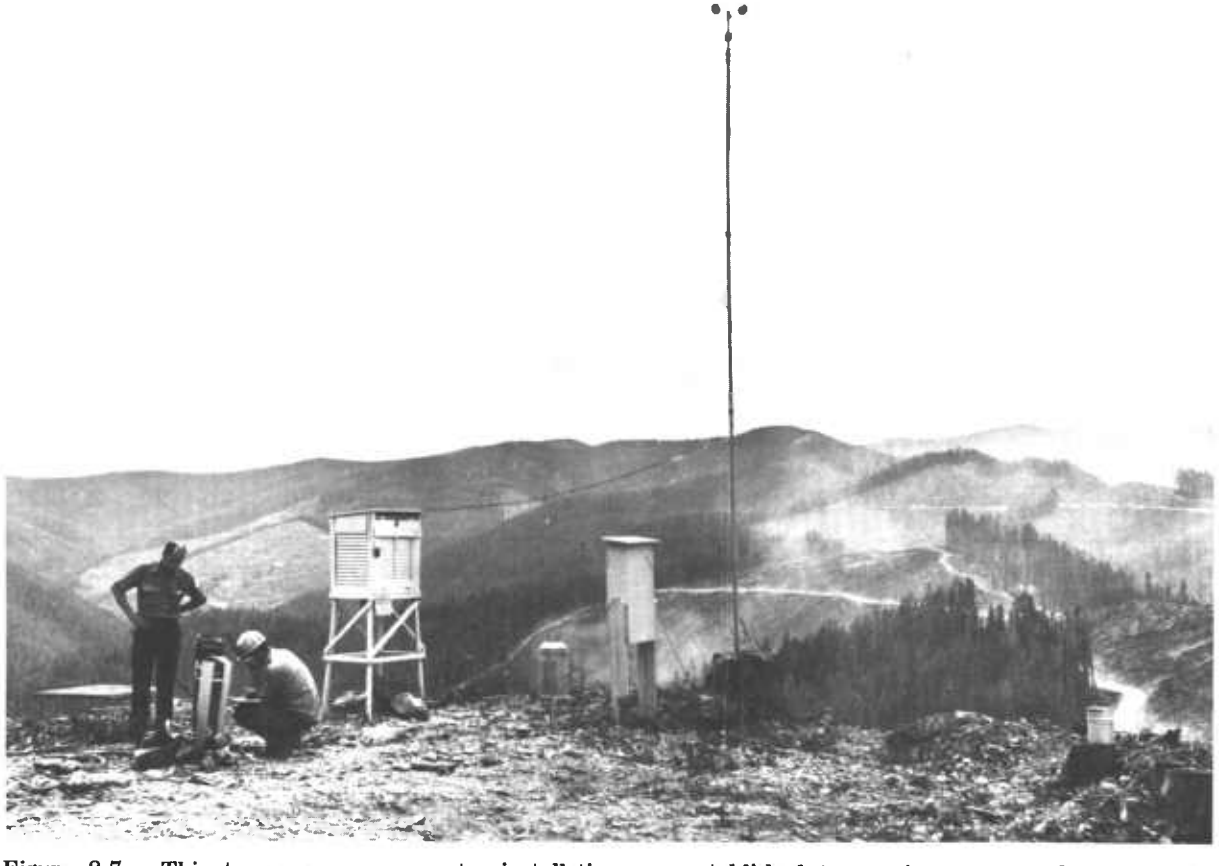


Figure 8.7. — This temporary anemometer installation was established to monitor weather for prescribed burning operations.

LOOKOUT LIGHTNING PROTECTION

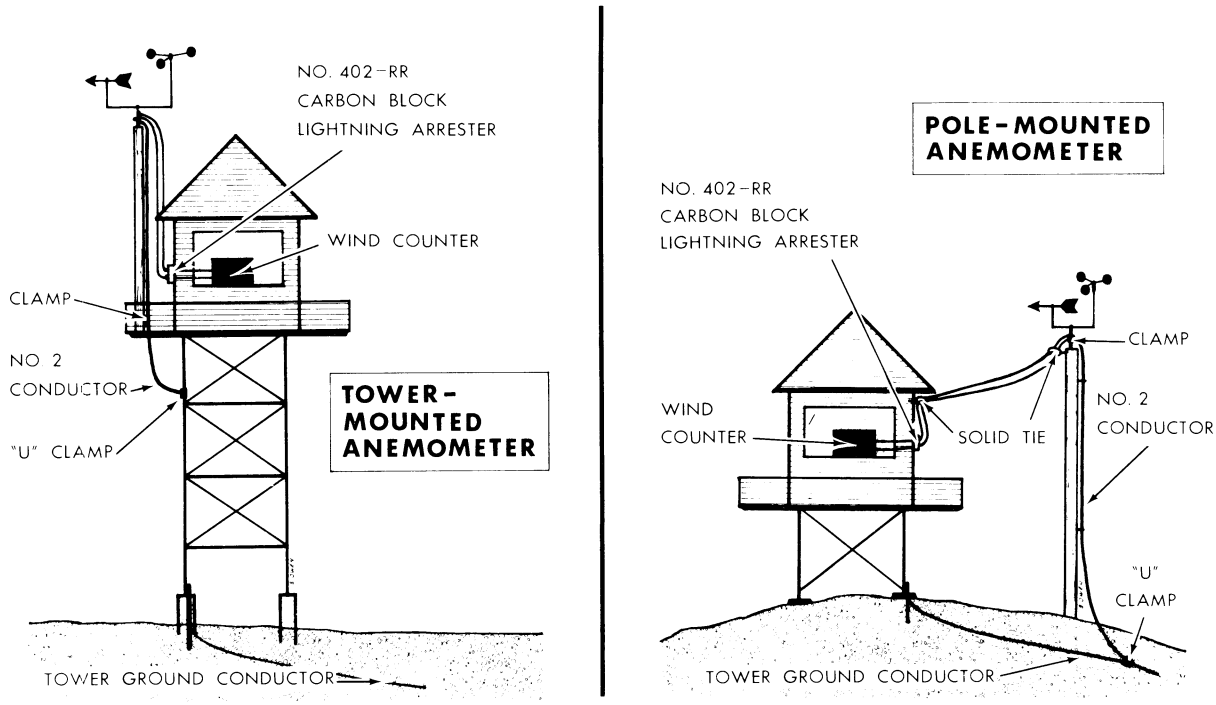


Figure 8.8. — Suggested method for obtaining adequate lightning protection at lookout anemometer installations: *Left*, Anemometer pole on tower; *right*, anemometer pole on ground.

Ground Installation

The following procedures apply if the anemometer is mounted on a pole in the ground, either at a lookout station (fig. 8.8) or at a valley bottom station (fig. 8.9):

1. Clamp a piece of #2 copper conductor onto the pole (if pipe) or the anemometer itself (if pole is wood).

2. If a ground wire from an existing lightning protection system is available nearby, run the conductor down the pole and clamp onto this ground wire.

3. If an existing ground wire is not available, install a ground rod near the pole and run the conductor down to it.

4. Install a carbon block lightning arrester (#402-RR or equivalent) on the tower leg or exterior of the building where the readout device is located. Before the wire connecting the anemometer to the readout device enters the building, it must pass through this arrester. Be

VALLEY STATION LIGHTNING PROTECTION

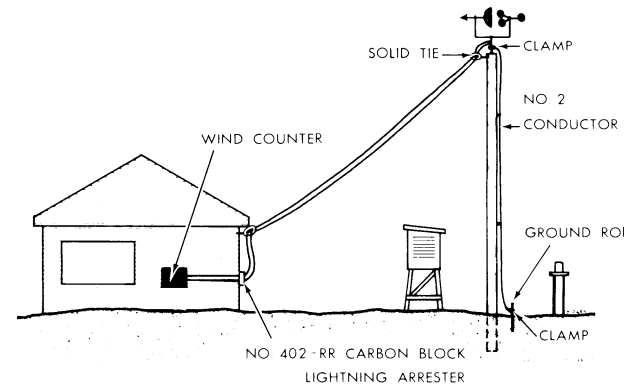


Figure 8.9. — Suggested method for obtaining adequate lightning protection at valley bottom anemometer installations.

certain that the wire is solidly connected to both the anemometer pole and the tower or building it is entering.

CROSS REFERENCE: Description 3.1; Operation 13; Maintenance 19.

8.6 WIND COUNTER

Location

The location of the wind counter is largely a matter of observer convenience. If periodic windspeed observations are required throughout the day, or if the observation interval is relatively long, an office installation may be desirable (fig. 8.10). When making office installations, be certain that appropriate lightning protection regulations are observed.

If the wind counter is located at the weather station, its installation must not interfere with exposure requirements of other instruments. The instrument shelter is for temperature-sensitive instruments and is not an acceptable location for a wind counter. A small weatherproof cabinet, located about 4½ feet above the ground on or near the anemometer pole, makes a handy wind counter installation (fig. 8.11). Plans for constructing the cabinet shown in figure 8.11 are provided in the Appendix.

Figure 8.10. — The wind counter and wind direction indicator are often installed in the fire dispatcher's office.

Figure 8.11. — A small accessory cabinet for installation of wind counter and wind direction readout device. The upper part of the cabinet can be used for tools and supplies.

Installation

Weatherproof insulated copper lead-in wire should be used to connect the wind counter to the anemometer. When connecting the battery to the counter, be sure to observe polarity of the battery wires.

An important consideration when installing a wind counter is the relationship between length and diameter of wire, electrical resistance, and battery voltage. As the line distance between anemometer and wind counter increases, the resistance increases; thus, you may need additional voltage when very long line distances are involved. The diameter of the wire can modify the above relationship since resistance decreases as the diameter of the wire increases. A final and potentially complicating factor is that too much voltage can burn the anemometer contacts.

The 10-minute wind counter, as a case in point, can be remotely located for as much as a mile without increased voltage providing a #20 or #22 copperweld twin-conductor wire is used for connecting the anemometer to the battery (USDA Forest Service 1969).

Because of the above factors, it is recommended that an electronic technician check the proposed design before installation and operation.

CROSS REFERENCE: Description 3.1; Operation 13.1, 13.2; Maintenance 19.11, 19.12. 20.

8.7 WIND VANE

Location

A wind vane equipped with an attached readout device is recommended for use at the standard fire-weather station. The vane can be mounted on the same pole as the anemometer (figs 3.1 and 8.4).

The wind direction readout device can be located either in the office (fig. 8.10) or at the weather station, depending on observer convenience. If located in an office, proper lightning protection practices should be observed. If located at the weather station, the readout device can be installed in the same cabinet as the wind counter (fig. 8.11).

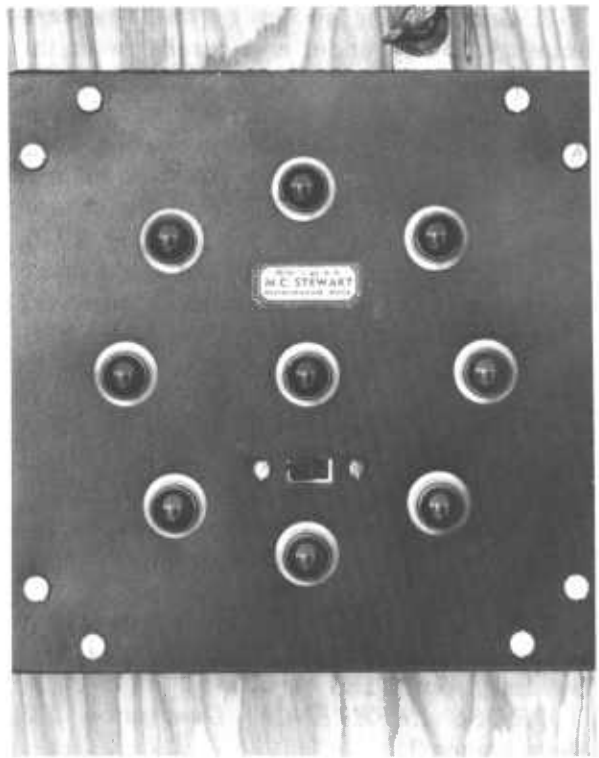


Figure 8.12. — Wind direction indicator. Lighted lamps indicate wind direction.

Installation

The two most important items when installing a wind direction system are:

1. Proper orientation of the wind vane in relation to true north.
2. Careful wiring of the readout device to the wind vane so that the direction indicated on the readout device corresponds to the direction indicated by the vane.

Use insulated, weatherproof cable to connect wind vane to readout device. A 10-lead cable is required for the wind direction indicator in figure 8.12.

True North Orientation

The following procedure is useful for obtaining proper orientation of both the Stewart and other makes of wind vanes:

1. Remove the front cover from the wind vane housing.
2. Rotate the wind vane arrow until the north contact is closed, causing the "north" indicator lamp to light.

3. Scribe a line on top of the wind vane housing directly under and parallel with the shaft of the arrow.

4. Replace front cover and extend the scribe line down the face of the housing.

5. Paint scribe mark, or install a strip of plastic tape, so it is visible from the ground when the wind vane is on the pole (fig. 8.13).

6. Drive a stake so that it is directly under the center of the wind vane housing, when the wind vane is in operating position. Use a compass and sight a line from this stake (point A) to true north.

7. Drive a second stake (point B) about 100 feet from point A along the sighted line to true north.

8. While the wind vane is in operating position, backsight a line from point B to the painted scribe line on the wind vane.

9. Adjust position of the wind vane until the line sighted from point B to the wind vane is exactly south (180°).

CROSS REFERENCE: Description 3.2; Maintenance 21.

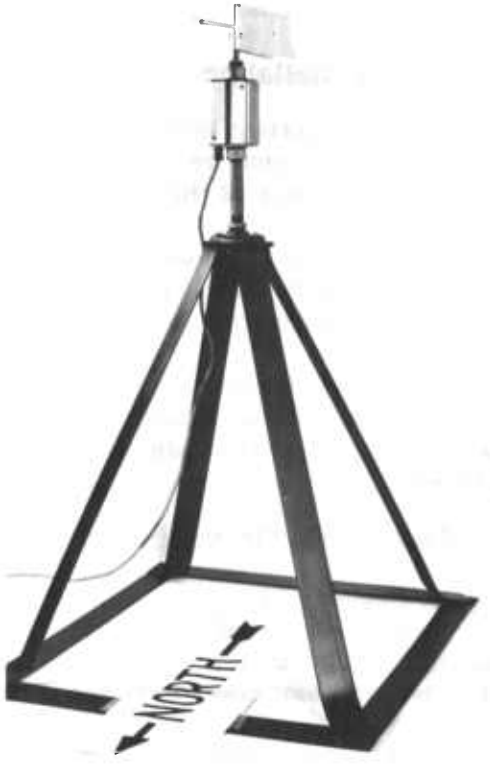


Figure 8.13. — Wind vane with scribe mark to assist in true north orientation.

8.8 STANDARD 8-INCH RAIN GAGE

Stands or mounts for both the large and small capacity 8-inch rain gage are shown in figures 4.2, 4.3, 8.4, and 8.14. The installation should be level, plumb, and firmly fixed in the ground (fig. 8.14). The top of the gage should be 36 inches above the ground.

When properly installed and located, the rain gage will be far enough away from high obstacles so that a 45° angle from the top of the gage will clear any such obstacle (fig. 8.4).

CROSS REFERENCE: Description 4.1; Operation 14.1; Maintenance 22.1.

8.9 RECORDING RAIN GAGE

The factors governing standard rain gage exposure apply equally to the location of recording rain gages. Mount the instrument at ground level on a heavy wooden or concrete base. The installation must be level, plumb, and windfirm.

Figure 8.14. — The rain gage installation should be level and plumb.

Figure 8.15. — Recording rain gage mounted on tower for snow measurement.

If the gage will be used to measure snow, install it on a platform or tower (fig. 8.15). The height will depend on the expected depth of accumulated snow. If the gage is left on a tower or platform year-round, it should not be used to obtain precipitation data during snow-free periods. Rather a standard gage installed with its top 3 feet above the ground should be used. This is necessary to insure data comparability with other locations. The recording rain gage record can be used to obtain time and duration of precipitation regardless of method of installation or time of year.

CROSS REFERENCE: Description 4.1; Operation 13.4; Maintenance 22.2-22.3.

8.10 FUEL MOISTURE STICKS

Duff Bed

Prepare a bed of coniferous needles or hardwood leaves 2 inches deep over a 3-foot-square area. The ground surface beneath the duff bed usually requires treatment of some sort to eliminate herbaceous vegetation. Place the needles on the surface of the ground (not in a pit) to assure normal runoff of water after a rain. The purpose of the duff bed is to provide a standard reflection surface and to prevent hard rains from splashing mud on the sticks. A burlap sack fastened to the ground under the sticks would be a good substitute if litter were not readily available.

Stick Exposure

Weathering, i.e., the effects of sun, rain, wind, and repeated wetting and drying, reduces the ovendry weight of fuel moisture sticks over time. For this reason, install a new set of indicator sticks at the beginning of each season and, if necessary, periodically throughout the season. Install the sticks several days prior to the date measurements are to start so they have sufficient time to attain equilibrium with the surrounding air. Expose the sticks in a horizontal position 10 inches above a fresh bed of dry needles or leaves. Place two galvanized wire racks 16 inches apart over the duff bed to support the sticks (fig. 8.16).

Screening

In the past, at many fire-weather stations of the open type, fuel moisture sticks have been shaded in an attempt to simulate the effect of a forest canopy on the moisture content of fuels on the forest floor. This shading is accomplished by use of screens.

In the Western States, a double layer of 14-mesh wire screen held taut in a 3-foot-square frame 13 inches above the ground has been used to produce a degree of shade about equal to that existing on an old-growth area from which three-fourths of the canopy has been removed (fig. 8.17). This practice, however, has generally been discontinued at fire-weather stations.

Whether or not screening is used depends on the objective of the fuel stick measurements. If the measurements are being taken to make decisions on when to broadcast burn a clearcut unit, for example, screening should not be used since there would be no tree canopy over the fuel complex being appraised. **Current fire-danger rating procedures do not use screens.**

CROSS REFERENCE: Description 5.1,5.2; Operation 15; Maintenance 23.

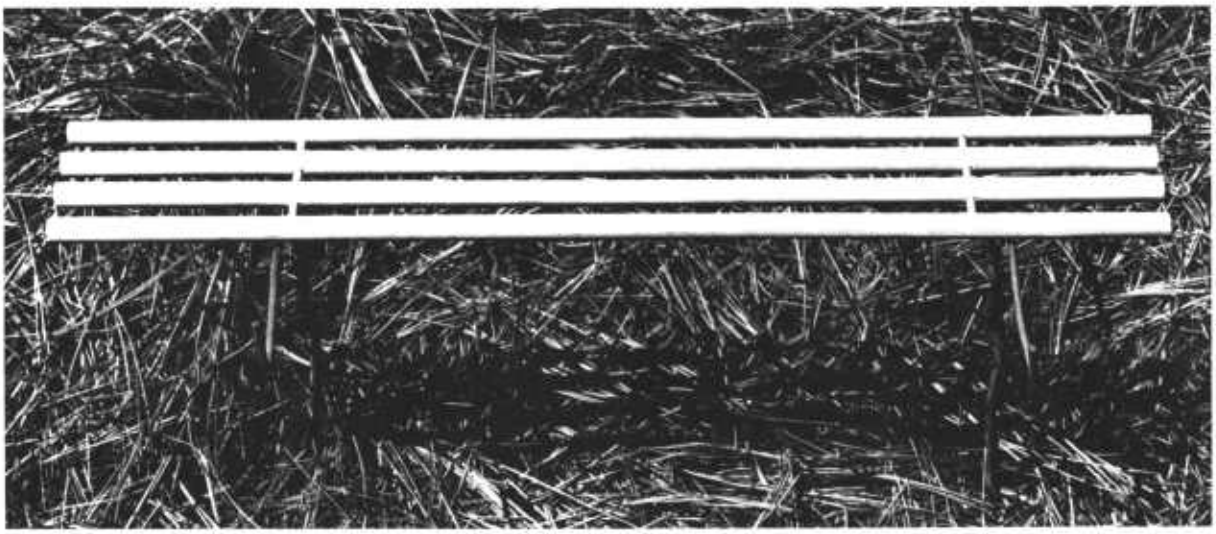


Figure 8.16. — Fuel moisture stick installation over a bed of coniferous needles.

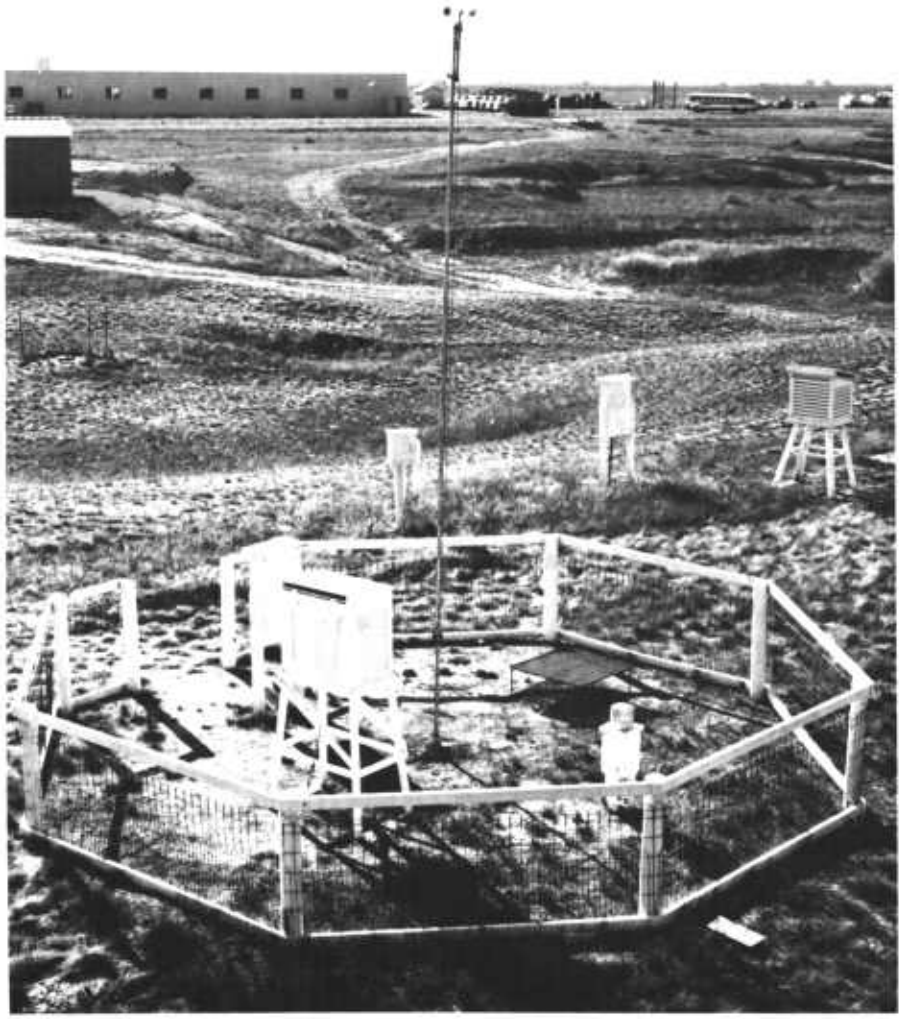


Figure 8.17. — Screen installed over fuel stick at valley station to simulate shade of forest canopy.

8.11 FUEL MOISTURE SCALE

An Appalachian scale mounted in an Appalachian scale shelter is recommended for weighing fuel moisture sticks at standard fire-weather stations (figs. 5.2 and 8.4). Construction plans for the Appalachian shelter are in the Appendix.

The scale shelter should be plumb and firmly secured to the ground. Its location should be such that it neither shades the fuel sticks nor interferes with the exposure of the instrument shelter or rain gage.

Install the scale on the mounting board, or backplate, of the shelter and level it as shown in figure 8.18. The scale must be exactly square and plumb to yield accurate readings. Once the scale is properly mounted in the shelter, easy zero adjustment can be obtained by manipulating the three wing nuts located around the face of the scale.

CROSS REFERENCE: Description 5.3; Operation 15; Maintenance 24.

Figure 8.18. — Appalachian scale installed in an Appalachian shelter. Both the shelter and the scale should be level and plumb.

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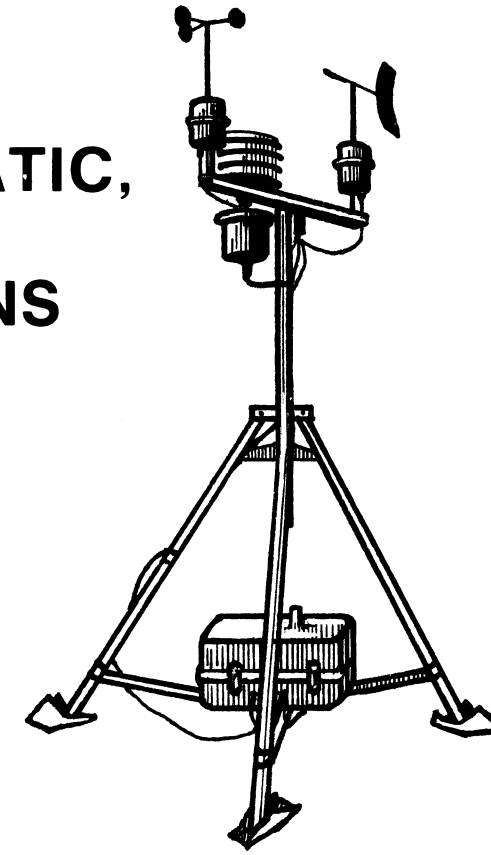
CHAPTER 9

PORTABLE, AUTOMATIC, AND REMOTE WEATHER STATIONS



A detailed treatment of portable, automatic, and remote weather stations is beyond the scope of this handbook. The fire manager should be aware of their existence and their potential application for fire-weather purposes. For these reasons, a brief discussion of each follows. Further information can be obtained from the references provided.

9.1 PORTABLE WEATHER STATIONS

A portable weather station is one designed and packaged for easy transport, installation, and operation. A variety of such stations has been developed for recording data at wildfires, prescribed fires, and research field locations. They are also useful for checking out potential sites for permanent fire-weather stations.

The simplest, least expensive, and most popular portable unit is the belt weather kit (fig. 9.1). It is merely a collection of individually available instruments placed together in a common carrying case. The description, operating instructions, and maintenance requirements for belt weather kit components are included in the appropriate parts of this handbook.

Other portable units vary greatly in design, type of sensors used, accuracy of measurement, and overall reliability of operation. They range from the fairly simple, "homemade" units (USDA Forest Service 1964c) to fairly sophisticated commercial units.

The important point for observers to recognize is that the same fire-weather measurement principles that apply to permanent stations are equally applicable to portable stations. Observers should know how the instruments or sensors work, their accuracy and reliability, exposure requirements, and maintenance needs.

9.2 AUTOMATIC WEATHER STATIONS

Automatic weather stations are those having the capability to collect and display data without constant attention of an observer. Collected data are usually displayed on a dial or recorded continuously on a chart or tape. Some automatic stations developed for fire-weather purposes are also portable (Murray

and Countryman 1968). A number of highly sophisticated automatic weather stations are commercially available from major instrument companies, many of which are somewhat portable.

9.3 REMOTE WEATHER STATIONS

A remote weather station is one that collects data at one location and transmits it for readout at another location. Stations of this type are usually expensive and have a fairly high maintenance cost. A number have been incorporated into fire-weather collection networks throughout the country (Lewis 1966; Hauck and Taylor 1968).

The majority of remote stations transmit data via radio although transmission by land line is also feasible, especially where short distances are involved (Breuer 1968).

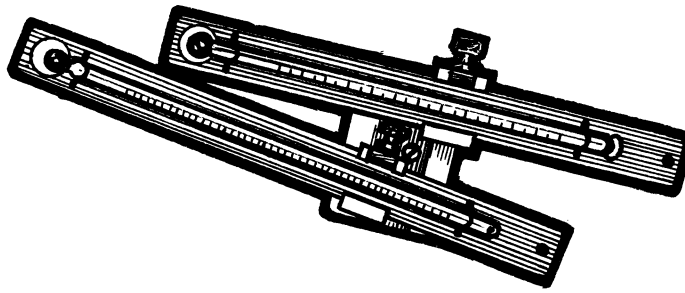
Figure 9.1. — Belt weather kit, open and closed view.

PART 3. OPERATING INSTRUCTIONS

Fire-weather stations are normally equipped with relatively simple instruments that are, for the most part, quite easy to operate. This is, in one sense, unfortunate because it leads many observers to feel that it is unnecessary to learn how to operate their instruments before attempting to obtain data from them. Furthermore, fire managers rarely see any need to provide training in instrument operation for their fire-weather observers. The net result of this casual attitude toward fire-weather observation is the perpetuation of improper measurement techniques and the routine collection of useless weather data.

Proper measurement techniques are governed to a large extent by the operating principles and the exposure requirements of the instruments involved. This is why these items are discussed at length in parts 1 and 2 of this handbook. An observer who understands instrument operating principles and exposure requirements will immediately see the logic in the operating instructions that follow.

CHAPTER 10



THERMOMETERS

10.1 READING THERMOMETERS

Observe the following precautions when reading any liquid-in-glass thermometer:

1. Do not touch the glass or hold hands near the bulb.

2. Do not breathe directly on the thermometer. Keep face back except when making final reading.

3. If instrument is hand-held, stand in shade or hold thermometer in shade of your body. Wherever possible, face into the wind.

4. Avoid parallax error when reading thermometers. Notice in figure 10.1 that a straight line from the observer's eye to the meniscus or the index forms a right angle with the thermometer stem.

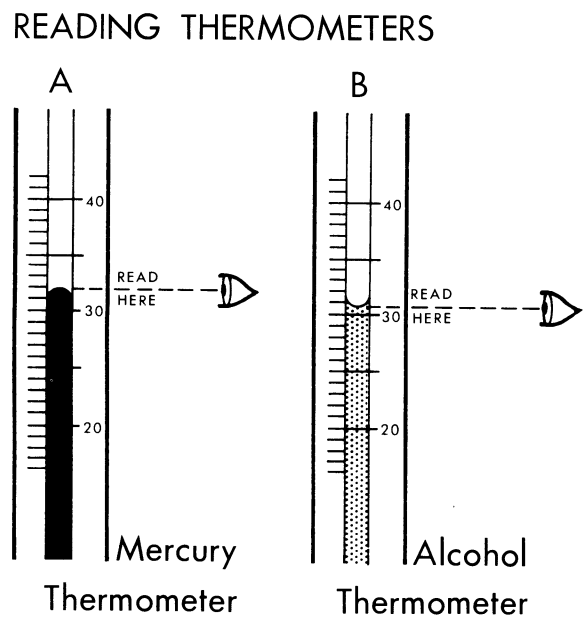


Figure 10.1. — Avoid parallax error when reading thermometers.

5. Doublecheck your reading before recording.

It is easy, for example, to incorrectly read a 55 instead of 65, or a 30 instead of a 40.

10.2 MAXIMUM-MINIMUM THERMOMETERS

Maximum and minimum temperatures, usually taken in the afternoon for fire rating purposes, normally refer to the 24-hour period between basic observation times. When this is the case, simply read the thermometers at observation time, record the readings, and reset the thermometers.

When taking observations at **the basic observation time,** remember that the maximum temperature read today cannot be lower than the dry-bulb temperature yesterday or today. Also, the minimum temperature, read today, cannot be higher than the dry-bulb temperature yesterday or today.

Maximum and minimum temperatures taken for climatological purposes often refer to the 24-hour period from midnight to midnight. When this is the case, follow this schedule:

At 0800 hours. — Read minimum temperature first and record as today's minimum temperature.

Read maximum temperature. If this maximum is higher than the maximum temperature recorded at yesterday's basic observation time, it means that temperature continued to rise yesterday after the reading was taken. Correct yesterday's entry accordingly.

Reset both thermometers — maximum thermometer first, minimum last.

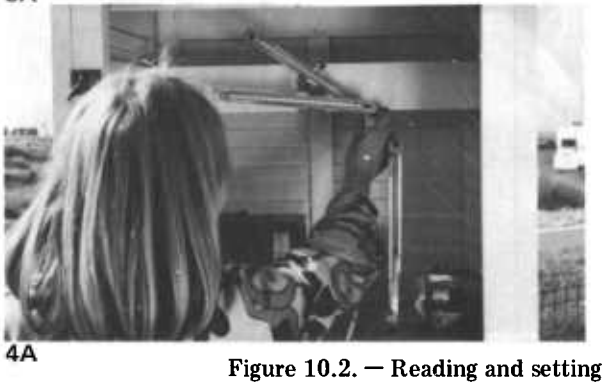
At basic observation time. — Read both thermometers. If minimum temperature is lower than today's 0800-hour reading, correct the minimum temperature entry on the observation record.

Read and record today's maximum temperature.

Reset both thermometers — maximum thermometer first, minimum last.

10.3 STANDARD MAXIMUM-MINIMUM THERMOMETERS

See figure 10.2 and procedure below for the correct reading and setting of standard



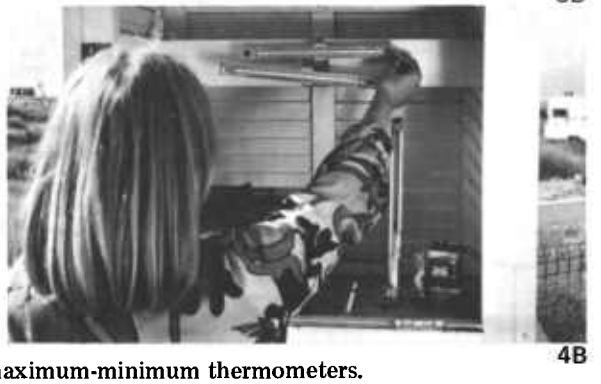


Figure 10.2. — Reading and setting maximum-minimum thermometers.

maximum-minimum thermometers in a Townsend Support. Caution: Always read the minimum thermometer first and reset it last because the index rod can easily jiggle and slide away from its correct position.

(1) Read minimum thermometer first.
   a. Read minimum temperature from the right or upper end of the index.
   b. Read current temperature from top of alcohol column.
   c. Do not reset at this time.

(2) Read maximum thermometer.
   a. Unlock and slowly lower maximum thermometer to a vertical position so that the mercury column is resting on the constriction in the tube.
   b. Read maximum temperature from the top of the mercury column.

(3) Set maximum thermometer first.
   a. Whirl until its reading agrees (within 1°) with reading at top of alcohol column of minimum thermometer (or dry bulb).
   b. Lock maximum thermometer to nearly horizontal position.

(4) Set minimum thermometer last.
   a. Invert until index drops to end of alcohol column.
   b. Return to its nearly horizontal position.

CROSS REFERENCE: Description 1.1; Installation and Exposure 8.2; Maintenance 16.1-16.4.

10.4 SIX'S COMBINED MAXIMUM-MINIMUM THERMOMETER

1. Read maximum and minimum temperatures at lower end of index (fig. 10.3).
   a. Read maximum temperature on right scale.
   b. Read minimum temperature on left scale.

2. Reset by using a magnet to draw each index rod down to the top of its mercury column (fig. 10.3).

CROSS REFERENCE: Description 1.1; Maintenance 16.1-16.3, 16.5.

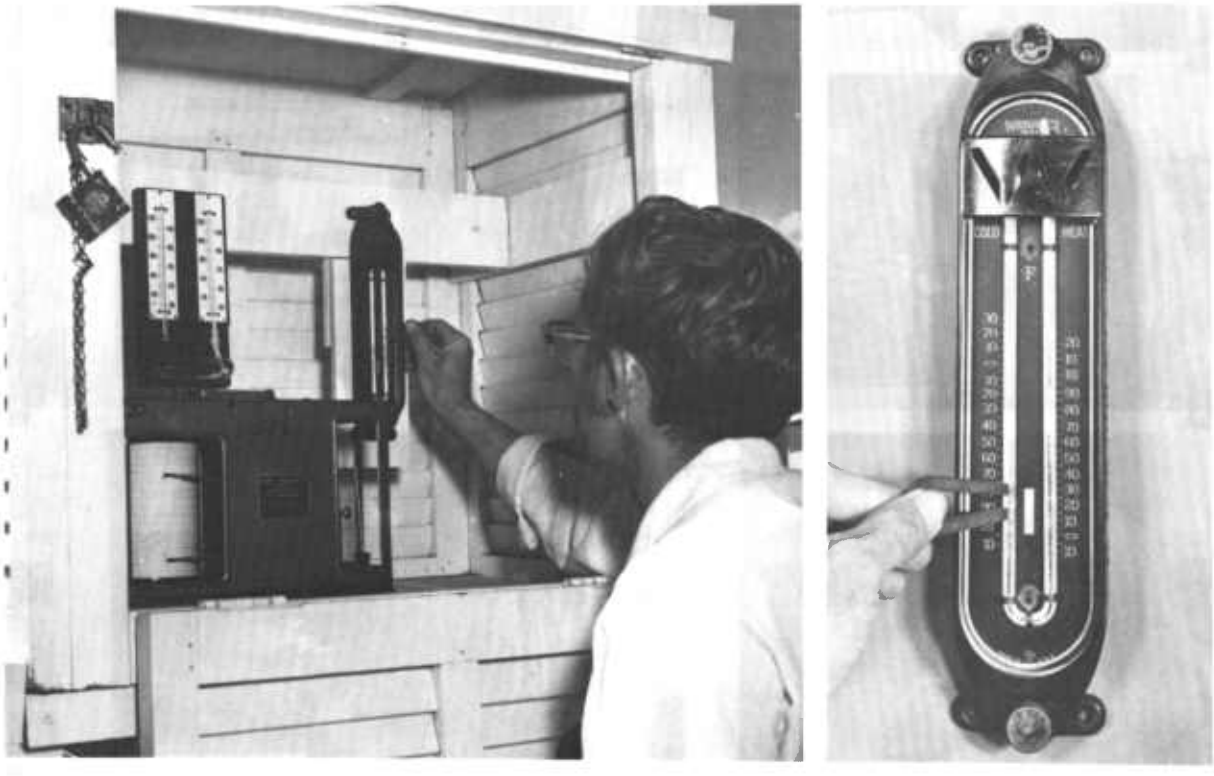


Figure 10.3. — Reading and setting Six's maximum-minimum thermometer.

CHAPTER 11

PSYCHROMETERS

Poor psychrometer operation is one of the most common observational errors at fire-weather stations. To obtain accurate results with the psychrometer, the observer must follow certain basic instructions, listed below, in addition to the specific operating instructions listed on the following pages.

11.1 GENERAL OPERATING INSTRUCTIONS

1. The two thermometers should agree within a half graduation when both are read as dry bulbs (wicking completely dry). Thermometers having 1° graduations should agree within 1/2°; those having 2° graduations within 1°; etc.

2. Wet-bulb wicking must be clean and snug fitting. Wicking should extend about 1 inch up the stem, above the bulb, to minimize error from heat transfer along the stem; and it should extend 1 inch below the tip of the bulb to serve as a water reservoir (fig. 11.1). Change wicking whenever it gets dirty, but at least every 2 weeks (see section 17.1).

3. Make observations in an area exposed to free air but protected from sunlight, radiated heat, and precipitation.

4. Wet the wet-bulb wick thoroughly just prior to ventilation (fig. 11.2). Do not get water on the dry bulb or it will tend to act as a wet bulb. Use only distilled water, clean rainwater, or other clean, mineral-free water of about air temperature. Unless the water container is capped, the water will be cooler than free air.

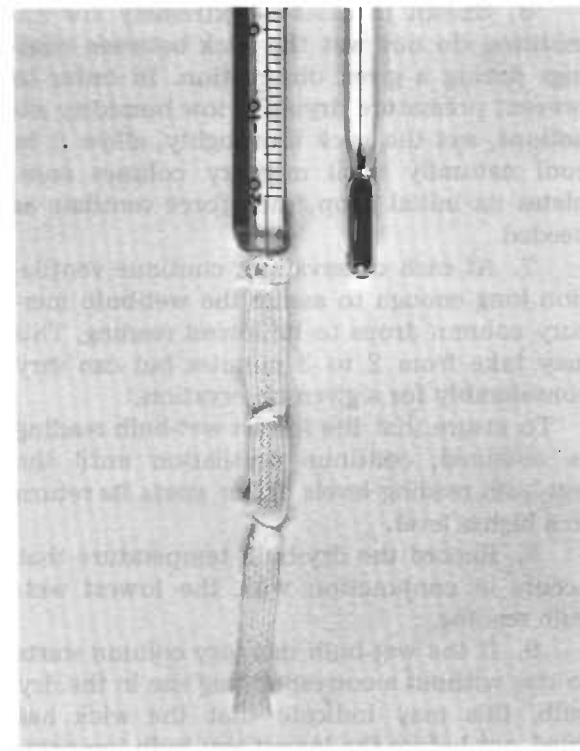


Figure 11.1. — A properly installed wick on wet- and dry-bulb psychrometer.

Figure 11.2. — Thoroughly wet the wick of electric fan psychrometer prior to taking measurements.

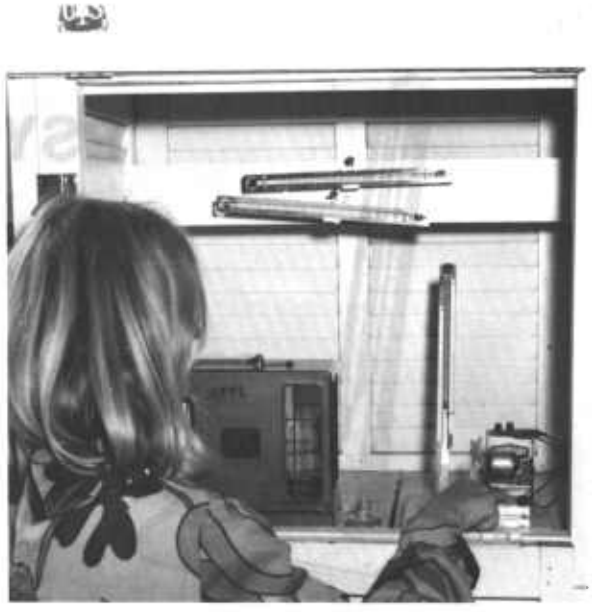


Figure 11.3. — Do not wet the wick during ventilation of the thermometers.

5. Do not allow the wick to extend into the water container either during operation or while the psychrometer is not in use (fig. 11.3).

6. Except in cases of extremely low humidities, do not wet the wick between readings during a given observation. In order to prevent premature drying in low humidity situations, wet the wick thoroughly, allow it to cool naturally until mercury column completes its initial drop, then force ventilate as needed.

7. At each observation, continue ventilation long enough to assure the wet-bulb mercury column drops to its lowest reading. This may take from 2 to 3 minutes but can vary considerably for a given observation.

To insure that the lowest wet-bulb reading is obtained, continue ventilation until the wet-bulb reading levels off or starts its return to a higher level.

8. Record the dry-bulb temperature that occurs in conjunction with the lowest wet-bulb reading.

9. If the wet-bulb mercury column starts to rise without a corresponding rise in the dry bulb, this may indicate that the wick has dried out before the lowest wet-bulb temperature was reached. In this case, wet the wick again, allow it to precool from natural ventilation, then start forced ventilation. Repeat procedure for reading wet and dry bulbs.

10. Do not allow body heat or breath to influence thermometer readings. Avoid touching and breathing on thermometers when taking final readings. Face wind when making observations outside an instrument shelter.

11. Refer to Relative Humidity and Dewpoint tables provided in back of this book to obtain relative humidity and dewpoint values from wet- and dry-bulb readings (see section 2.1). Caution: Relative Humidity and Dewpoint tables and slide rules provided with many psychrometers are for use at sea level only.

12. For fire-weather purposes, the thermometer readings are usually recorded to the nearest degree. Half degree readings are recorded to the next higher degree. Increased accuracy, if required, can be obtained by recording to the nearest half degree and interpolating in the psychrometric tables.

13. During freezing weather, the water in the wick must be completely frozen before attempting a reading. Remove all old ice by dipping in warm water prior to observation.

If wick is dry, wet it about 15 minutes before observation to allow a thin coat of ice to

form. Ventilation will speed up this process as will touching the wet bulb with a piece of clean ice or cold metal.

Ventilate thermometers until wet-bulb temperature drops to a steady point below 32° F.; read first the wet bulb and then the dry bulb.

11.2 ELECTRIC FAN PSYCHROMETER

The electric fan psychrometer is designed for operation in an instrument shelter. Refer to section 11.1 for general instructions.

1. *Check the wick.* — It must be clean, snug, and of the proper length (fig. 11.1).

2. *Wet the wick.* — Saturate with clean, mineral-free water of about air temperature just prior to an observation. After wetting, replace cover and set water container aside (fig. 11.2).

3. *Ventilate the thermometers.* — Air must flow at a minimum rate of 15 feet per second. Replace batteries at the first sign of weakness. Be sure the motor wires are properly attached to the battery. If they are not, the fan will turn backwards and insufficient ventilation will result (fig. 11.3).

4. *Read the wet bulb.* — Read the wet bulb first. Watch the top of the mercury column as it retreats down the stem. It will drop slowly and then come to rest for several seconds, sometimes longer. Take a reading at this point. Continue to watch the column as it will either start to return up the stem or drop still farther down the stem.

If the wet bulb remains steady or starts to rise (and the wick is still moist) you have already noted the lowest wet-bulb temperature. If the column drops farther down the stem, repeat the process of reading and watching until you have noted the lowest point reached by the top of the mercury column before it starts its rise back up the stem.

5. *Read the dry bulb.* — Take a dry-bulb reading immediately after each wet-bulb reading. The correct dry-bulb reading will be the one occurring with the lowest wet-bulb reading.

CROSS REFERENCE: Description 2.2; Installation and Exposure 8.3; Maintenance 17.1.-17.4.

11.3 PORTABLE ELECTRIC FAN PSYCHROMETER

Operate in an open but shaded area for best results. Avoid heat sources. Point air duct openings away from body during operation. If possible, place instrument on a flat surface facing into the wind with thermometers facing upward for easier readings. Refer to section 11.1 for general operating instructions. Specific operating instructions are as follows:

1. *Check the wick.* — It must be clean, snug, and of the proper length (fig. 11.1).

2. *Check the thermometers.* — Inspect to see if mercury column has separated during transit. Allow thermometers to stabilize with temperature of air at observation site.

3. *Wet the wick.* — Remove air duct and point thermometer bulbs downward. Thoroughly wet wick with water of about air temperature, but do not oversaturate. Avoid getting water into the fan compartment. Replace air duct (fig. 11.4).

Figure 11.4. — Carefully wet wick. Avoid getting water on dry bulb.

4. *Ventilate the thermometers.* — Be sure air duct fits snugly against thermometer housing to avoid air leakage. Turn fan on. If fan blows air out of duct instead of sucking in, check battery installation. If motor slows down or thermometer light dims, replace batteries.

5. *Read the wet bulb.* — Read the wet bulb first. Watch the top of the mercury column as it retreats down the stem (fig. 11.5). It will drop slowly and then come to rest for several seconds, sometimes longer. Take a reading at this point. Continue to watch the column as it will either start to return up the stem or drop still farther down the stem.

If the wet bulb remains steady or starts to rise (and the wick is still moist) you have already noted the lowest wet-bulb temperature. If the column drops farther down the stem, repeat the process of reading and watching until you have noted the lowest point reached by the top of the mercury column before it starts its rise back up the stem.

6. *Read the dry bulb.* — Take a dry-bulb reading immediately after each wet-bulb reading. The correct dry-bulb reading will be the one taken immediately after the lowest wet-bulb reading has been obtained.

CROSS REFERENCE: Description 2.2; Maintenance 17.1-17.3, 17.6.

11.4 HAND FAN PSYCHROMETER

The hand fan psychrometer is designed for use in an instrument shelter. Except for ventilation requirements, specific operating instructions are identical to those for the electric fan psychrometer. The observer should also refer to general operating instructions in section 11.1. Ventilation is accomplished by hand cranking the fan. Rapid cranking must continue without interruption until the lowest wet-bulb reading is obtained (fig. 11.6).

CROSS REFERENCE: Description 2.2; Installation and Exposure 8.3; Maintenance 17.1-17.3, 17.5.

11.5 SLING PSYCHROMETERS

In order to obtain reasonably good accuracy with sling psychrometers, stand in shaded open area away from buildings and away from obstacles that may be struck during whirling.

If light conditions permit, face the wind to avoid influence of body heat on thermometers. Do not let sunlight or rain strike the thermometers. Refer to general operating instructions in section 11.1. Specific operating instructions follow:

1. *Check the instrument.* — Be sure handle and chain are in good repair. Check thermome-

Figure 11.5. — Observe top of wet-bulb column as it retreats down the stem.

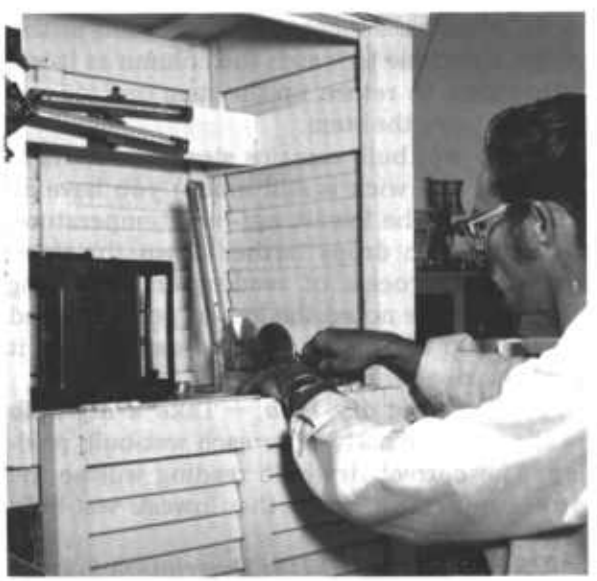


Figure 11.6. — Rapid cranking of hand fan must continue until lowest wet-bulb temperature occurs.

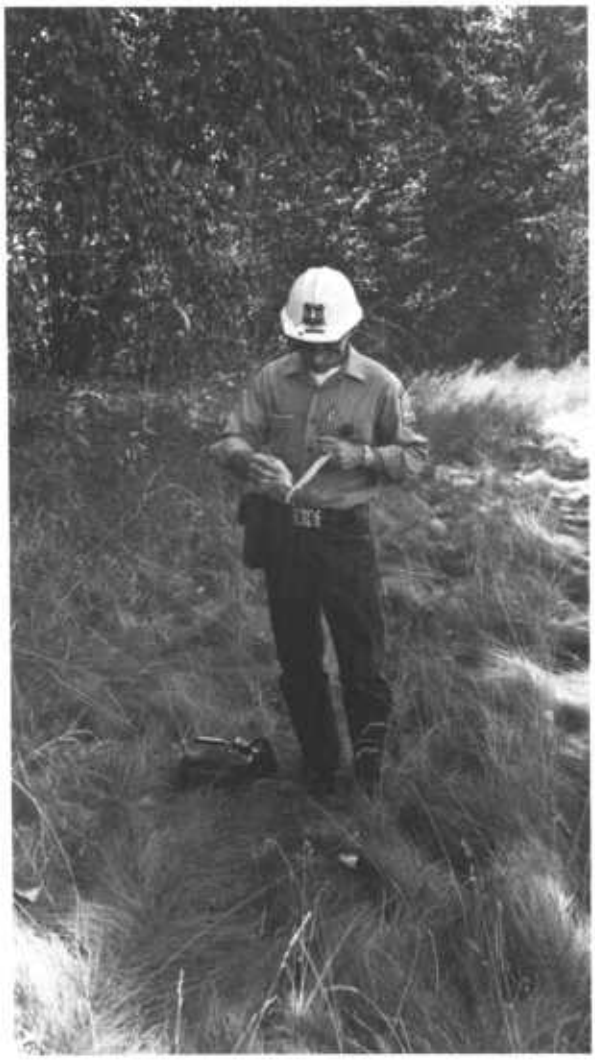


Figure 11.7. — Stand in shade. Wet the sling psychrometer wick prior to whirling.

Figure 11.8. — Whirl sling psychrometer at full arm's length.

ter column for separations. Be sure the thermometers are firmly mounted to housing.

2. *Check the wick.* — It must be clean, of the proper length, and securely fastened to bulb (fig. 11.1).

3. *Wet the wick.* — Saturate with a clean mineral-free water of about air temperature just prior to making observation (fig. 11.7).

4. *Ventilate the thermometers.* — Whirl at full arm's length with arm parallel to the ground for about 1 minute at the rate of about 200 whirls per minute (fig. 11.8).

If the humidity is very low and no shade is available, premature drying of the wet bulb may be a problem. This may be prevented by waving the psychrometer in body shade (fig. 11.9), open to breeze if possible for a few minutes before whirling in full sunshine. This will often reduce the amount of whirling required.

5. *Read the wet bulb.* — Note wet-bulb temperature. Whirl another 40 or 50 times and read again. If wet bulb is lower than first reading, continue to whirl and read until it will not go any lower. When lowest point is reached, read and record (fig. 11.10).

6. *Read the dry bulb.* — Read dry bulb immediately after lowest wet bulb is obtained.

CROSS REFERENCE: Description 2.2; Maintenance 17.1-17.3, 17.8.

Figure 11.9. — Whirl psychrometer in body shade if no other shade is available.

Figure 11.10. — Read and record lowest wet bulb obtained.

Figure 11.11. — For best results fan the hygrometer wick before reading.

11.6 WET- AND DRY-BULB HYGROMETER

The wet- and dry-bulb hygrometer is designed for simple operation; merely read the thermometers whenever a relative humidity and dewpoint determination is desired. This procedure assumes that adequate ventilation of the wet bulb will be accomplished naturally.

In order to achieve the maximum accuracy possible with this instrument, fan the thermometers using a piece of cardboard for about 3 minutes before reading (fig. 11.11). Read the thermometers to the nearest 1° F.

CROSS REFERENCE: Description 2.2.

11.7 THE MORTARBOARD PSYCHROMETER

Operating instructions are as follows:

1. *Check the thermometers.* — Sun must not be striking any portion of thermometers. If shading is required, reading must be delayed until thermometers stabilize.

2. *Check the wick.* — Wick must be clean and saturated with clean, mineral-free water. Wick may dry out under extended periods of low humidity (below 30 percent for several hours). To correct this situation, wet the wick several minutes before taking a reading. If wetting is required, allow the wet bulb to stabilize prior to reading.

3. *Check the water cup.* — The cap should fit tightly on the cup and the tubing should extend from near the bottom of the cup to 1 inch below the tip of the wet bulb. The cup should be at least half full of clean, mineral-free water before starting an observation.

4. *Insure proper ventilation.* — Insufficient ventilation of the thermometers may occur if winds are less than 3 miles per hour at any time or less than 6 miles per hour during dry weather (30-percent relative humidity or less). To insure proper ventilation, use a piece of cardboard to fan the thermometer until a minimum wet-bulb reading is obtained. If an electric fan has been installed, refer to section 11.2.

5. *Read the wet bulb.* — Eyes should be directly in line with top edge of mercury column to avoid a false reading (fig. 11.12).

6. *Read the dry bulb.* — Read immediately after wet bulb. During freezing weather, follow general instructions given for wet- and dry-bulb psychrometers.

CROSS REFERENCE: Description 2.2; Maintenance 17.1-17.3, 17.7.

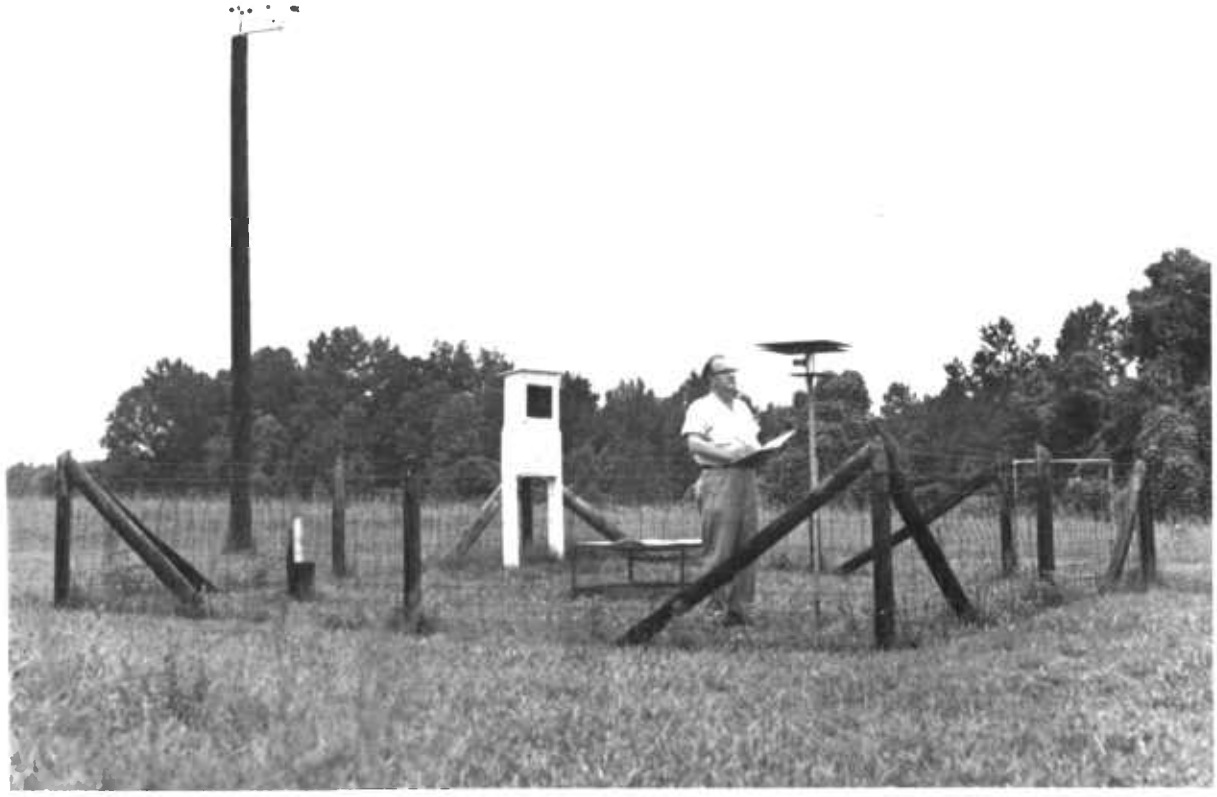
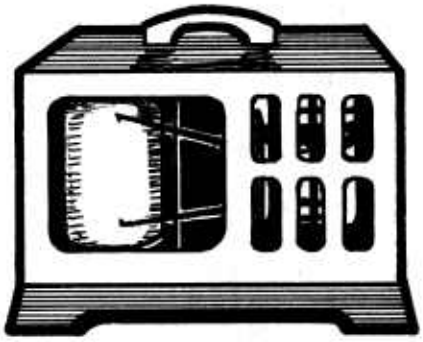


Figure 11.12. — Reading mortarboard psychrometer.

CHAPTER 12



HYGROTHERMOGRAPHS

Expose hygrothermographs in an instrument shelter 4 feet above the ground. For best results, follow the operating procedure outlined below.

12.1 CHANGING THE CHART

Before installing a new chart, write the station name and number and the beginning date in the spaces provided at the end of the chart (fig. 2.10).

To remove the old chart:

1. Lift pens off chart using shifting lever.
2. Unlock and raise cover.
3. Lift drum from spindle being careful not to hit pens.
4. Record "off time" on chart near last pen mark. Record ending date on chart (fig. 2.10).
5. Pull clip and remove chart from drum. Avoid smearing recent, wet portion of trace with fingers.
6. Wind clock (fig. 12.1).

To install a new chart:

1. Place chart down snug against the bottom lip of the drum and wrap it tightly around the drum.
2. Insert clip if nonslotted cylinder (fig. 12.2). If slotted cylinder, insert ends of chart into slot on cylinder.
3. Replace drum on spindle. Position drum so that chart time is a little faster than correct time.
4. The pens should be refilled with ink, if necessary (see below).

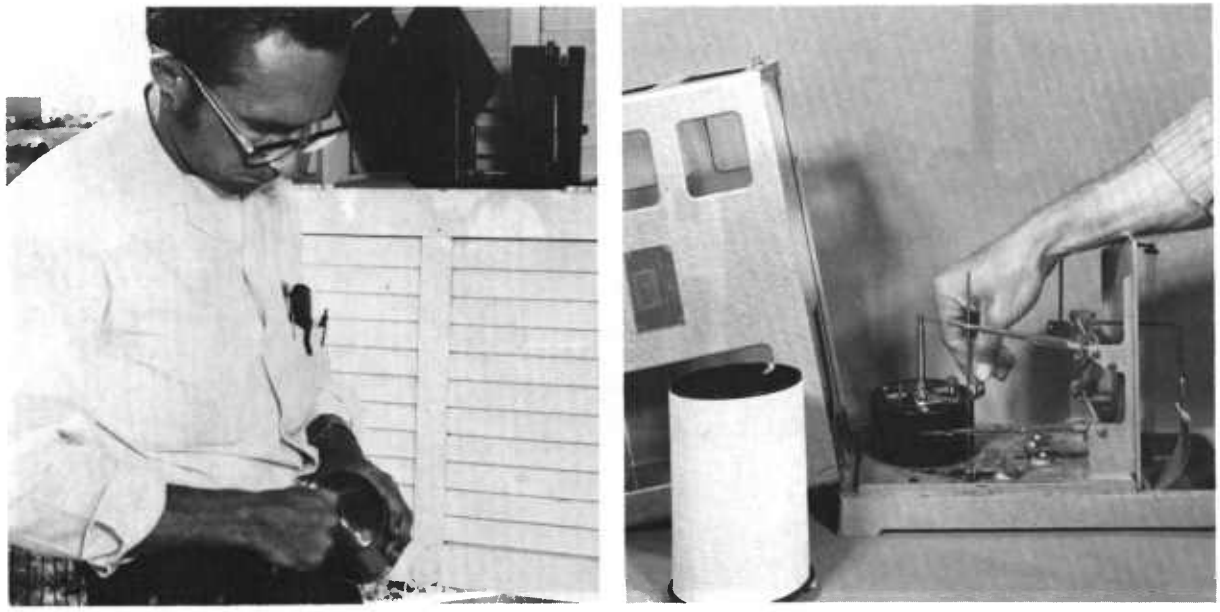


Figure 12.1. — Winding clock on hygrothermograph: *Left*, Clock in drum type; *right*, clock on base type.

Figure 12.2. — To avoid losing part of the hygrothermograph record, install tapered charts on non-slotted cylinders.

5. Return pens to chart using shifting lever. Check ink flow by slightly rotating drum back and forth.

6. Turn drum to place pens at correct chart time by rotating drum counterclockwise. This takes up any slack in the gears.

7. Lower and latch cover.

12.2 INKING THE PENS

1. Use purple glycerine base ink made specifically for hygrothermographs (fig. 12.3).

2. Fill pen until ink first shows at each end. If filled until ink bulges out, overinking of the chart might result.

3. In damp weather the ink, being deliquescent, absorbs moisture so less ink should then be used. It is especially important to keep pen points sharp during damp weather (see section 18.2).

4. To start flow of ink, draw a piece of chart paper through the points. This cleans out old residue and draws a film of ink to the points.

12.3 CHECKING THE CALIBRATION

If daily readings are taken, check calibration at the standard observation time. If station is not visited daily, check calibration whenever

Figure 12.3. — Inking the pens of a hygrothermograph.

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Figure 12.4. — Use a clean, dry, camel's hair brush to remove dirt and dust.

chart is changed. Because of the lag time of the sensors, calibration checks should be done only when temperature and humidity are holding steady. Procedures are as follows:

1. Inspect instrument for obvious mechanical deficiencies.

2. Use a clean, dry, camel's hair brush to remove dust or dirt.

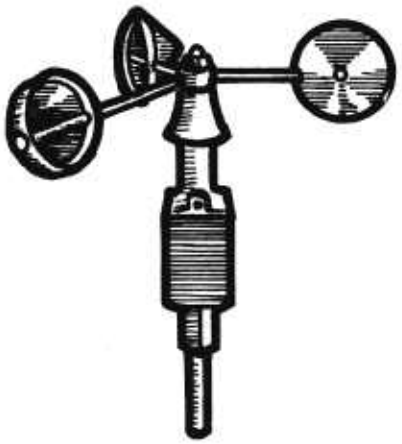
3. To make a time mark, lightly deflect each pen downward to obtain a short vertical line on the chart. Do not deflect humidity pen upward as this may apply excessive force on the hairs and foul up the adjustment. Record actual time near mark or on observation record. Compare chart time with actual time and compare time indicated by upper pen with that of lower pen; then, make necessary adjustment.

4. Compare maximum, minimum, and current temperatures on chart with values obtained from the maximum, minimum, and dry-bulb thermometers (see section 11.1); then, make necessary adjustments.

5. Compare current relative humidity on chart with reading obtained from the psychrometer (see section 11.1). Observe relative humidity trace for evidence of range elongation or shortening; then. make necessary adjustments.

CROSS REFERENCE: Description 2.3; Installation and Exposure 8.4; Maintenance 18.

CHAPTER 13



ANEMOMETERS

The following instructions are for anemometers exposed at the 20-foot standard height (20 feet plus adjustment for nearby obstructions and surface irregularities, see section 8.5). If the anemometer height is greater than the 20-foot standard height, the observed windspeed must be corrected according to special instructions at the end of this section.

Windspeed refers to the average speed of the wind over a period of 10 minutes. This use of a 10-minute average windspeed for fire-weather and fire-danger observation is compatible with recognized standards for measuring wind (World Meteorological Organization 1969).

13.1 1/60-MILE CONTACTING ANEMOMETER

Readout by Reset Counter Equipped With Timer

1. Reset dial to zero, if not already done.
2. Set timer.
3. When timer stops, read dial (fig. 13.1).
4. Record correct average 10-minute windspeed in miles per hour by placing decimal point before last number on counter dial.
5. Reset dial to zero.
6. If average windspeed for other than 10 minutes is desired, simply set desired interval on timer and divide final count by that time interval.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5, 8.6; Maintenance 19, 20.2.

Readout by Reset Counter

1. Reset dial to zero, if not already done.
2. Using the "off-on" switch, start both the counter and stopwatch. If using a watch with a sweep second hand, start counter as second hand passes 12.
3. After exactly 10 minutes, stop counter.

Figure 13.1. — Windspeed and direction can be obtained from readout devices conveniently located on the ground.

4. Record correct average 10-minute windspeed in miles per hour by placing decimal point before last number on counter dial.

5. Reset counter to zero.

6. If average windspeed for other than 10 minutes is desired, let counter run for desired interval and divide final count by that interval.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5, 8.6; Maintenance 19, 20.3, 20.4.

Readout by Nonreset Counter

1. Record numbers on the counter dial.

2. Start counter and stopwatch. If using a watch with sweep second hand, start counter as second hand passes 12.

3. After exactly 10 minutes stop counter.

4. Record numbers on the counter dial.

5. Calculate average 10-minute windspeed by subtracting the beginning count from the ending count. Place a decimal point before the last number of the result and record.

6. If average windspeed for other than 10 minutes is required, let counter run for the desired interval, subtract ending count from beginning count, and divide difference by the interval used.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5, 8.6; Maintenance 19, 20.

Figure 13.2. — Detailed view of anemometer dial. Dial indicates 104 miles of accumulated air movement past the anemometer cups.

Readout by Buzzer or Flasher

1. Close switch on buzzer or flasher.

2. Immediately after the first flash or buzz, record the time or start the stopwatch.

3. Count number of flashes or buzzes for the desired time interval. The time interval applicable to this type of indicator is usually 4 minutes.

4. Open the switch.

5. Calculate average windspeed by dividing the total count by the time interval.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5, 8.6; Maintenance 19, 20.1.

13.2 ANEMOMETERS WITH SELF-CONTAINED READOUT

Readout by Self-Contained Counter

1. Record starting count.

2. Record count at end of interval for which average windspeed is desired.

3. Subtract beginning count from ending count and divide difference by the time interval.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5, 8.6; Maintenance 19.11.

Readout by Self-Contained Dial

1. Read dial at beginning of the period for which average windspeed is desired.

   a. Read the inner dial first. The index for the inner dial is located in the outer dial. It is a small "zero" through which is drawn a vertical line (fig. 13.2). The inner dial is graduated in tens and hundreds of miles.

   b. Read the outer dial. The index is a small pointer located above and just to the left of the large dial (fig. 13.2). When the glass cover is on the dial, the eye has to be lowered slightly to see this second index. The outer dial is

graduated in miles and tenths of a mile.

c. The total reading is obtained by adding the miles indicated on the outer dial to the miles indicated on the inner dial.

2. Read the dial at the end of the period for which average windspeed is desired.

3. Subtract beginning reading from ending reading and divide the difference by the elapsed time (minutes, hours, days, etc.).

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5, 8.6; Maintenance 19.1-19.4, 19.12.

13.3 CORRECTING WINDSPEED OBSERVATIONS TAKEN AT HEIGHTS GREATER THAN 20-FOOT STANDARD

An anemometer installed on top of a building or mounted on a fire lookout tower may exceed the 20-foot standard height, even after making adjustment for nearby obstructions.

If the total height of the anemometer is greater than the required height (see section 8.5), the resulting windspeed observations must be adjusted.

Table 13.1 (Cramer and Moltzau 1968) provides conversion factors to adjust windspeeds obtained from anemometers exposed at heights greater than 20-foot standard.

To make necessary adjustment:

1. Determine total height for a 20-foot standard ground installation.

2. Determine total height of anemometer (in feet) above ground.

3. Determine height of anemometer above 20-foot standard height (item 1 minus item 2).

4. Using item 3, look up conversion factor in table 13.1.

5. Multiply observed windspeed by conversion factor. Result is 20-foot standard windspeed.

13.4 HAND-HELD WIND METER

1. Face the wind and hold the meter at arm's length about head high; have the scale side of meter facing you (fig. 13.3).

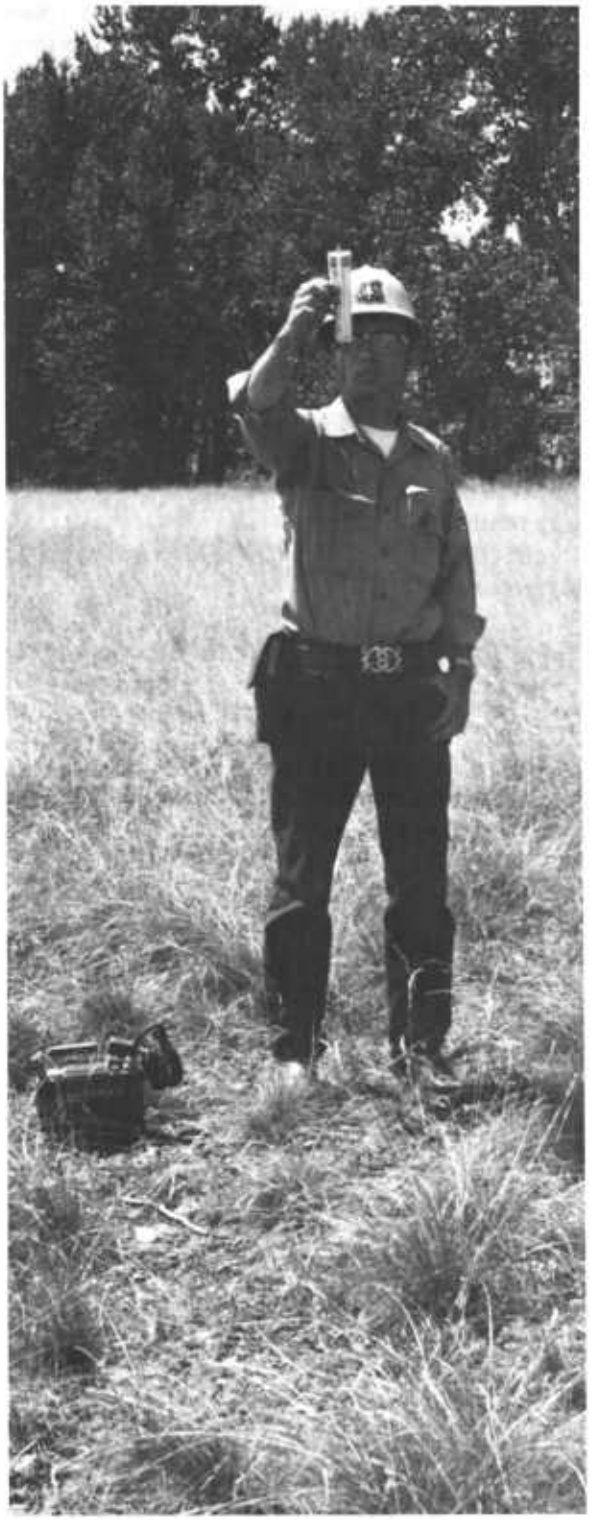


Figure 13.3. — Assume a face-into-wind position when using hand-held wind meter. Keep fingers clear of top stem when measuring winds less than 10 m.p.h.

2. Hold the instrument about midway from either end being careful not to block the two holes at the bottom or small pinhole in top stem.

3. Observe action of the ball in relation to left scale. If it is "bouncing" around between 2 and 9, read from the left or low scale (fig. 13.3). If ball is rising up near 10 on left scale, cover the top stem with your finger and read from the right or high scale (fig. 13.4).

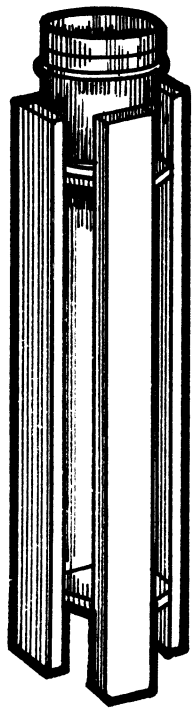
4. To obtain a reading, observe height attained by the ball in relation to the appropriate scale value (see item 3 above). Usually the height of the ball will vary considerably even during a short period; consequently, a certain amount of subjective averaging is often necessary to obtain a value.

CROSS REFERENCE: Description 3.1; Maintenance 19.14.

Table 13.1. — *Conversion factors for adjusting windspeeds taken at heights in excess of 20-foot standard height*

Height of anemometer above 20-foot standard (Feet)	Conversion factor
0	1.00
10	.95
20	.91
30	.88
40	.86
50	.84
60	.82
70	.81
80	.80
105	.78
130	.75
180	.72

Figure 13.4. — Face wind and cover top stem with finger to measure winds in excess of 10 m.p.h.



RAIN GAGES

14.1 THE STANDARD 8-INCH RAIN GAGE

The following operating instructions apply to both the large capacity and the smaller capacity FS standard 8-inch-diameter rain gages:

Measuring Normal Amounts of Rain

1. Remove collector from top of the rain gage (fig. 14.1A).
2. Use a clean measuring stick and slowly lower it straight into the measuring tube (fig. 14.1B).
3. Remove the stick before water has a chance to creep up above the actual waterline.
4. Read the stick in inches and hundredths (fig. 14.1C). Normally, a precipitation measurement of less than one-half of 0.01 inch is recorded as a trace (T).
5. Empty the measuring tube (fig.14.1D) and replace it in the gage.
6. Replace the collector, making sure it rests squarely on top of the gage (fig. 14.1E).

Measuring Rain Where Measuring Tube Has Overflowed

1. Record a full tube as 0.50 inch if FS gage or 2.00 inches if traditional, large capacity gage.
2. Carefully lift the tube out and dump the water (fig. 14.2A).
3. Pour the water from the overflow cylinder into the measuring tube (fig. 14.2B).
4. Measure and record the amount if less than full tube. Repeat if necessary until all the water in the overflow cylinder has been measured.
5. Record the total of all the measurements taken.

Night or Early Morning Rains

To prevent loss by evaporation, measure night or early morning rains as soon as possible after rain stops. At the basic observation time, record the total of all measurements since the previous day's observation time.

Measuring Procedure When Ice or Snow Is Expected

1. Remove the collector and the measuring tube and store in a convenient place.
2. Leave the overflow cylinder in place to catch the precipitation.
3. Measure snowfall as soon as possible after ending. This will reduce the chance of error due to melting and evaporation under sunny conditions.
4. At measuring time, warm the overflow cylinder just enough to melt collected snow or ice but not enough to evaporate any water.
5. Pour the water into the measuring tube; then, measure and record.
6. If there is a large amount of snow or ice in the overflow cylinder, melting in the overflow cylinder can be speeded by carefully pouring in a known amount of hot water from the measuring tube. Subtract this known amount

Figure 14.1. — Measuring normal amounts of rain with FS rain gage: *A*, Remove collector; *B*, dip measuring stick into inner tube; *C*, read stick; *D*, empty tube; *E*, replace collector.

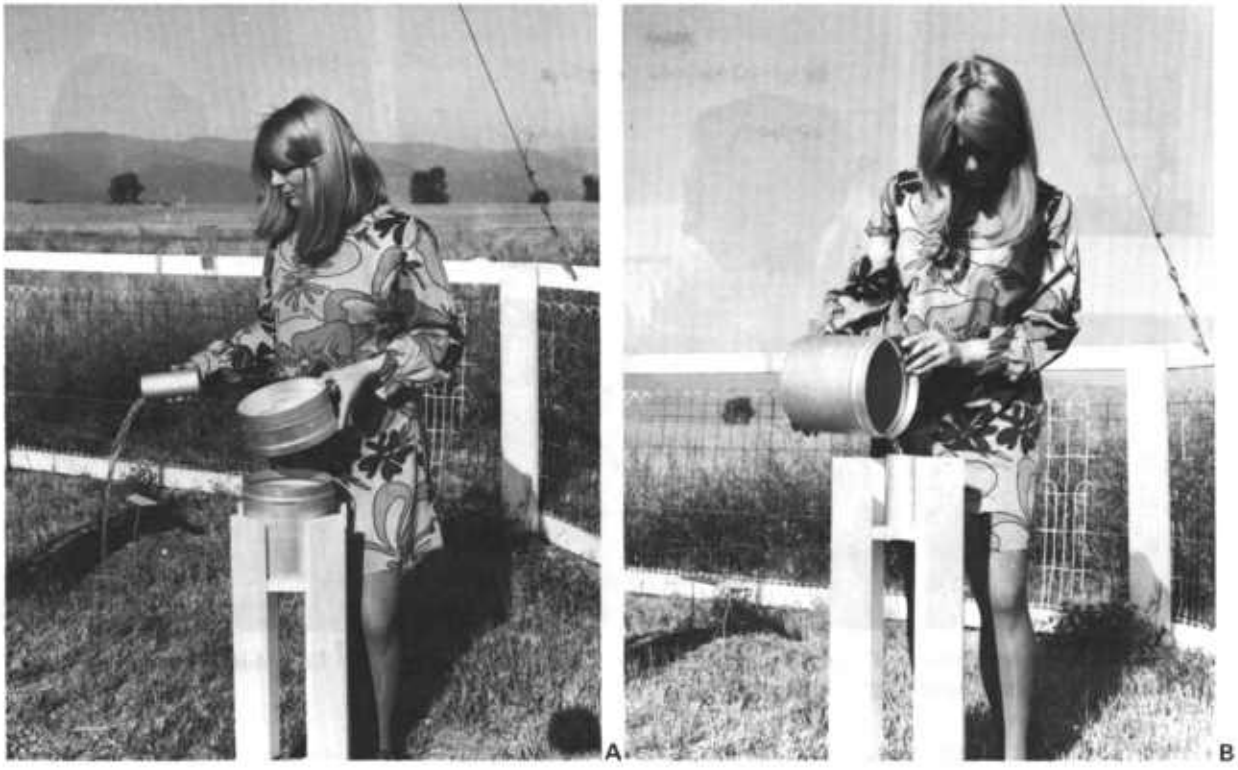


Figure 14.2. —Procedure when measuring tube overflows: *A*, Dump full tube and record 0.50 inch; *B*, pour excess into tube and measure.

from the total water poured out of the overflow cylinder.

Using a Snowboard to Measure Snowfall

Snowfall should be measured as soon after ending as possible. This may eliminate errors caused by the snow settling and becoming more compact.

1. Measure depth of new snow on board (cleared prior to snowfall) to nearest tenth of an inch.

2. Measure depth of accumulated snow to nearest tenth of an inch. (Total snow depth is often measured on nearby representative ground rather than on the snowboard.)

3. Using overflow can from 8-inch rain gage (as one would use a cookie cutter), position it over the new snow and press the can down to the snowboard.

4. Clear snow from around the overflow can.

5. Slide a sufficiently large sheet of cardboard or metal under the mouth of can, keeping good contact. Then turn can and sheet upright, tap or slide sheet to shake all of snow core into can, and remove sheet.

6. Melt the collected snow, pour the resulting water into the measuring tube from the rain gage, and measure water equivalent with rain gage measuring stick.

CROSS REFERENCE: Description 4.1; Installation and Exposure 8.8; Maintenance 22.

14.2 THE 4-INCH CLEAR PLASTIC GAGE

Measurement techniques are similar to those for the standard 8-inch gage except the level of water is read directly from the scale etched on the measuring tube (fig. 14.3). Be sure gage is positioned vertically before reading the scale. If more than 1 inch of rain occurs, causing the measuring tube to overflow, follow the procedure in section 14.1.

CROSS REFERENCE: Description 4.1; Maintenance 22.1.

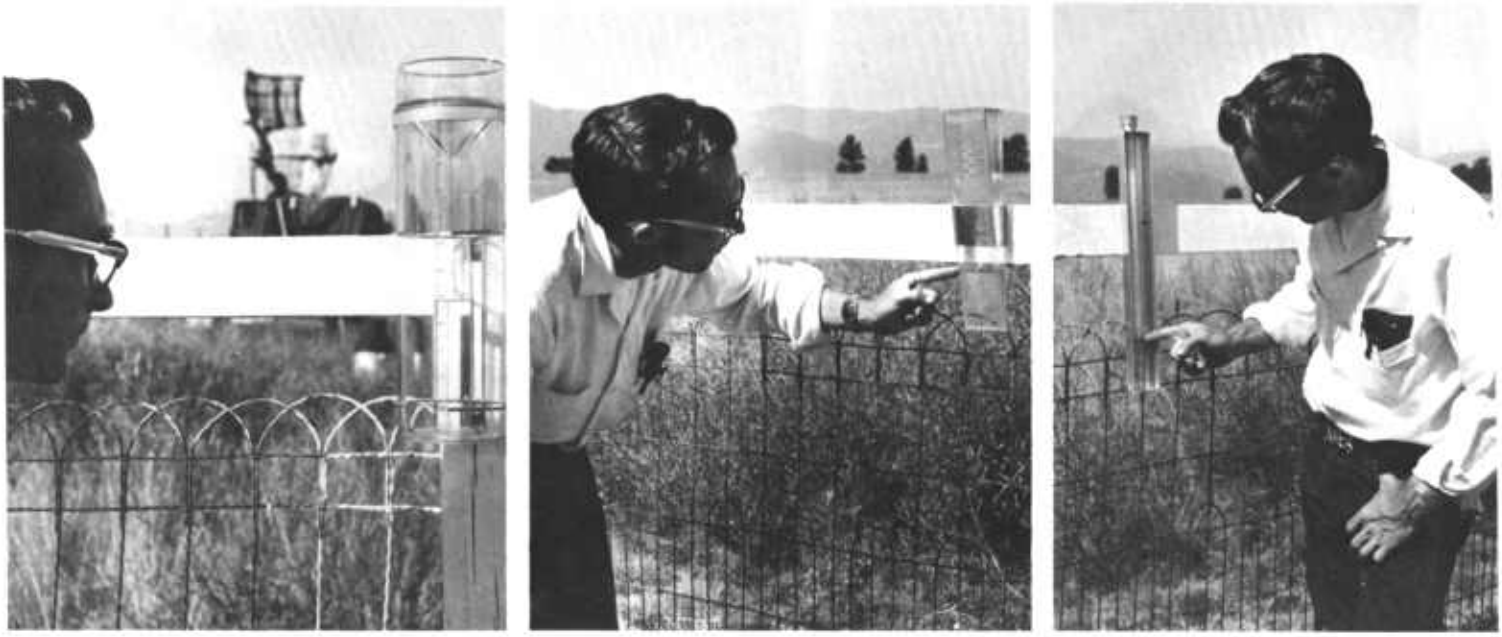


Figure 14.3. — Read amount of rainfall directly from scale on clear plastic gages: *Left*, 4-inch clear plastic gage; *center*, wedge-shaped gage; *right*, small orifice gage.

14.3 THE WEDGE-SHAPED GAGE

Make sure gage is positioned vertically and simply read the level of water directly from the scale etched on the gage (fig. 14.3). Measure precipitation as soon as possible after it occurs in order to reduce error due to evaporation losses.

CROSS REFERENCE: Description 4.1; Maintenance 22.1.

14.4 WEIGHING TYPE EQUIPPED WITH CLOCK DRIVE

1. Use the pen arm shifter and lift pen from chart.

2. Remove collector and bucket (fig. 14.4A). If there is water in the bucket, check to see if it was recorded on the chart. Empty bucket and replace (fig. 14.4B).

3. Remove chart drive cylinder and take off old chart. Note date and "time off." Prepare fresh chart by noting station name, date, and "time on" (fig. 4.7).

4. Install the fresh chart. Make sure it fits snugly and that it rests squarely on the lower lip of the cylinder (fig. 14.4C).

5. Wind the clock but do not overwind it (fig. 14.4D).

6. Replace chart drive cylinder and turn it counterclockwise until the correct time line on the chart is opposite the pen.

7. Refill the pen with ink. If necessary, draw a piece of hard paper through the nibs to start the flow of ink. A small corner piece of chart paper works fine.

8. Return pen to chart using pen arm shifter. Make final time adjustment if necessary.

9. Check pen setting for zero. The pen should rest on the bottom horizontal line of the chart (zero) when empty bucket is in place (fig. 14.4E). Make necessary adjustments in zero by using the fine adjustment thumbscrew.

10. Replace collector and close gage.

The above procedure assumes chart changes at the end of each chart scale period; i.e., 24-hour charts are changed each day, 7-day charts are changed each week.

Unless large precipitation amounts occur, charts having a 24-hour scale may be left on for a week if the pen is advanced slightly upward to a new line every day, with the date and time notations made. There should be a new starting line for the pen each day regardless of whether or not any precipitation has fallen.

A

C

B

D

E

Figure 14.4. — Weighing rain gage operation: *A*, Remove collector; *B*, empty bucket; *C*, install fresh chart; *D*, wind clock; *E*, zero pen.

Special Instructions for Use During Freezing Weather

1. Remove the funnel attached to the bottom of the collector and store it in a convenient place.

2. Place an antifreeze solution in the bucket. One such solution recommended by the National Weather Service consists of a mixture of 2 pounds commercial anhydrous calcium chloride (77 to 80 percent pure); 1¼ to 1½ quarts water, at room temperature; and 2 ounces SAE 10 motor oil.

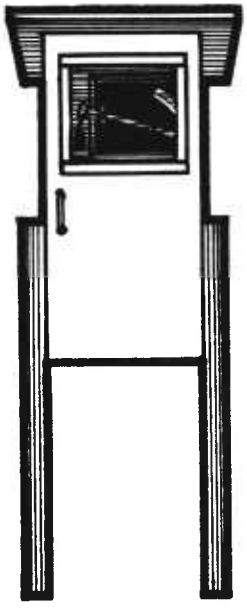
A commercial type of ethylene glycol preparation such as Prestone has been recommended as an alternative to the National Weather Service solution described above (Kidd 1960). Despite its higher cost, this type of preparation has the advantage of being noncorrosive (it actually provides a protective coating). It has the further advantage of minimizing the chance of top freezing since it does not have the settling tendency of the calcium chloride solution.

A small amount of SAE 10 motor oil should be added to the antifreeze to prevent evaporation if the gage is not checked daily.

3. Addition of the antifreeze will raise the zero of the pen arm. Note the level of this new zero. Using the fine adjustment thumbscrew, raise or lower the zero until the pen rests on the nearest horizontal chart line. This will aid in figuring precipitation amounts.

4. Let precipitation accumulate in the bucket until the antifreeze becomes too diluted to prevent freezing. When this occurs, empty the bucket and refill with a fresh solution.

CROSS REFERENCE: Description 4.1; Installation and Exposure 8.9; Maintenance 22.3.



FUEL MOISTURE SCALES

15.1 THE APPALACHIAN SCALE

The procedure for measuring the moisture content of the 1/2-inch ponderosa pine fuel moisture stick is as follows:

1. *Check the scale.* — Be sure that the sliding weight on the balance arm is set and locked at 100 grams. The weight is locked by tightening the set screw on top of the weight. Check calibration by hanging the 100-gram weight on the hook. Tap the pivot block lightly; the pointer should indicate zero (fig. 15.1). If adjustment is necessary, loosen the wing nuts and carefully move the scale until the pointer indicates zero.

2. *Remove the stick.* — Use a clean glove, piece of cloth, or paper and remove the stick from the wire rack. If dry, lightly brush away any dust, using a clean, soft bristle paint brush (fig. 15.2). If stick is wet, shake away any free moisture.

3. *Weigh the stick.* — Hang the stick on the scale arm (fig. 15.2). Steady the stick and let the pointer come to rest. As soon as the pointer comes to rest, tap the pivot block to overcome premature stopping due to friction; if windy close the shelter door (fig. 15.2) Then read the moisture content percent directly on the curved scale opposite the pointer, and record the results. Read the scale to the nearest whole percent (fig. 15.3). Guard against parallax error when reading scale.

4. *Replace the stick.* — Remove the stick from the scale and return to the wire racks. Make sure the same side faces up (brads down) and the screw hook end points north (fig. 15.4).

CROSS REFERENCE: Description 5.1, 5.3; Installation and Exposure 8.11; Maintenance 23, 24.1.

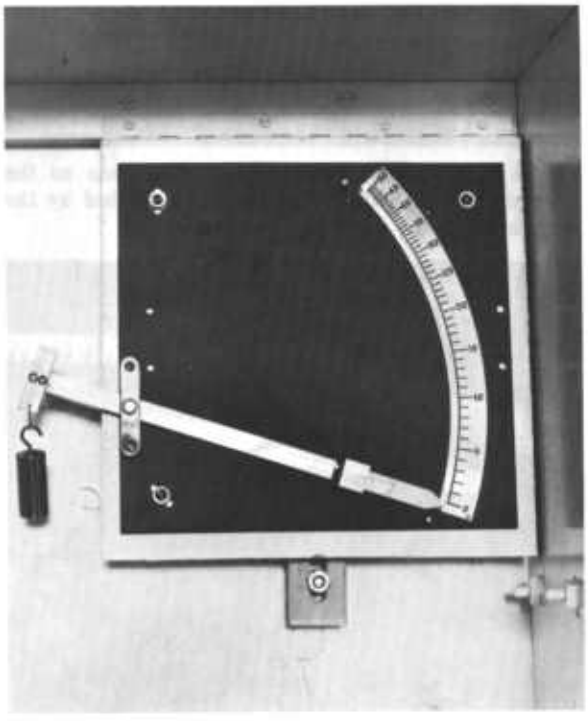


Figure 15.1. — Use a 100-gram test weight to check the calibration of the Appalachian scale.

Figure 15.2. — Weighing the stick: *Left*, Remove dust, dirt, etc.; *center*, carefully hang stick on scale; *right*, close door to protect stick from wind.

Figure 15.3. — This stick weighs 108 grams so the moisture content is 8 percent as indicated by the pointer.

Figure 15.4. — Replace stick on wire rack, hook north, brads down.

15.2 CHISHOLM PORTABLE SCALE

This scale can be hand held (fig. 15.5) but is much easier to use if it is hung on a post, tree, etc. To operate:

1. *Check the scale.* — Make sure that it is plumb and that the pointer moves freely. Check calibration with a 100-gram test weight.

2. *Remove the stick.* — Using a clean glove, piece of cloth, or paper, remove the stick from the wire rack. If dry, lightly brush dust off, using a good quality, soft bristle brush (fig. 15.2). If wet, shake off any free moisture.

3. *Weigh the stick.* — Carefully hang the stick on the hook provided. Gently tap the pointer. Read the moisture content percent from the graduated scale as indicated by the pointer (fig. 15.5).

4. *Replace the stick.* — Return to wire racks making sure that the same side is up (brads down) and the screw hook points north (fig. 15.4).

CROSS REFERENCE: Description 5.1, 5.3; Maintenance 23, 24.4.

15.3 WILLIAMS POCKET SCALE

1. Remove locking screw and cover.
2. Insert locking screw as handle.
3. Calibrate the scale by hanging cover (100 grams) on hook (fig. 15.6); any offset must be considered before recording the final value.

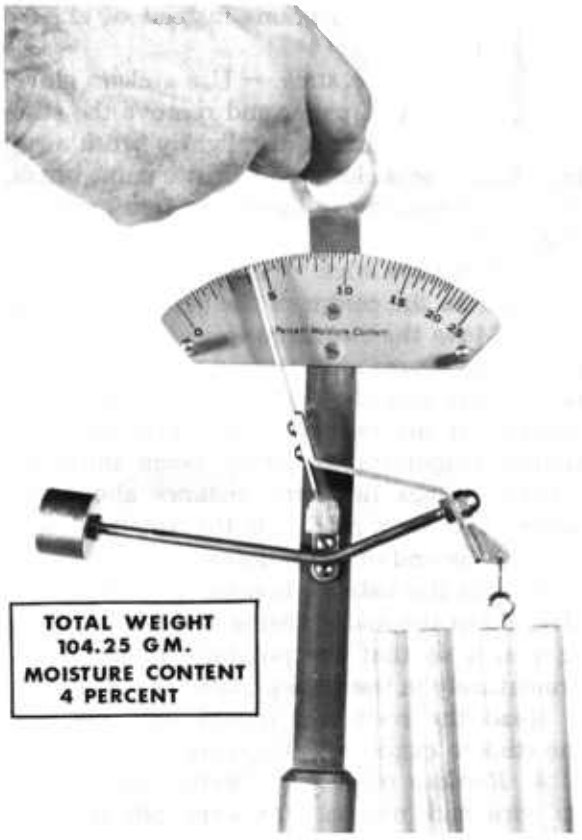


Figure 15.5. — Weighing fuel moisture stick on Chisholm portable scale. This stick weighs 104.25 grams so its moisture content is 4 percent as indicated by the pointer.

4. Remove cover and hang stick on the hook (fig. 15.7).

5. Turn circular weight until beam balances; at this point make sure the scale body is horizontal and the handle vertical.

6. Determine moisture content percent by adding together the reading from the scale on the rotating weight and adjusting the reading from the scale on the body (fig. 15.7). Recheck to make certain the figures are being read in the proper direction on the rotating scale.

CROSS REFERENCE: Description 5.1, 5.3; Maintenance 23, 24.3

15.4 TRIPLE BEAM BALANCE

1. *Check the balance.* — Dust off the balance pan using a clean, soft bristle paint brush. Place a 100-gram weight on the pan

Figure 15.6. — Check calibration of scale by using cover as a 100-gram test weight.

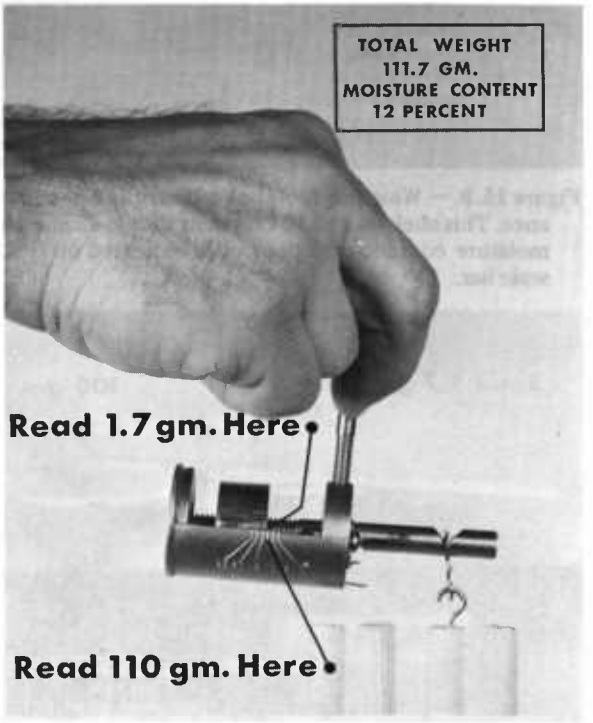


Figure 15.7. — Weighing fuel moisture stick on Williams pocket scale. This stick weighs 111.7 grams so moisture content is 12 percent as indicated on scale.

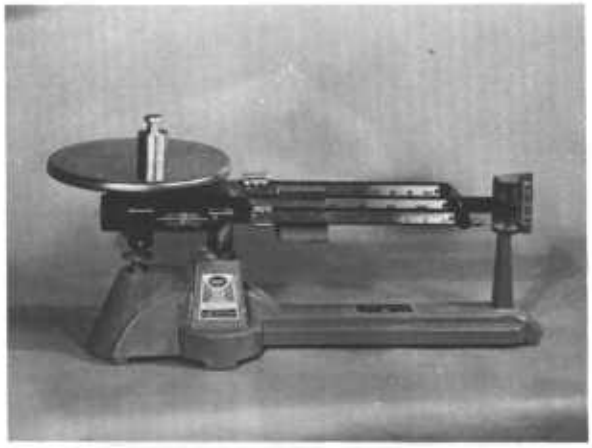


Figure 15.8. — Checking the balance of triple beam balance.

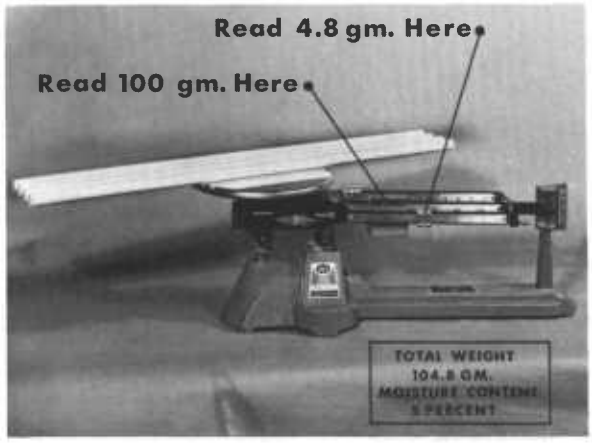


Figure 15.9. — Weighing fuel stick with triple beam balance. This stick weighs 104.8 grams thus indicating a moisture content of 5 percent as indicated on first scale bar.

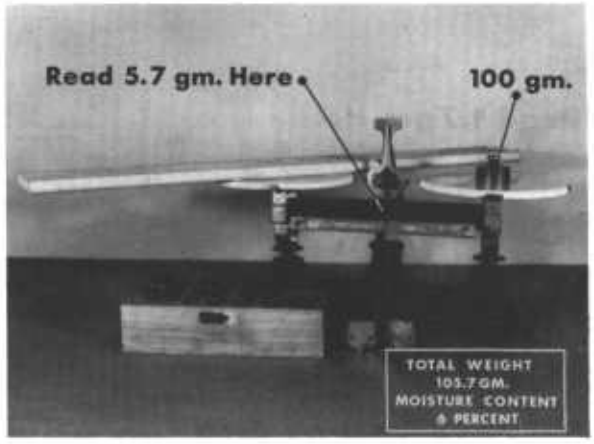


Figure 15.10. — Weighing fuel stick with Harvard balance. This stick weighs 105.7 grams thus indicating a moisture content of 6 percent as indicated on scale.

and balance at 100 grams instead of at zero (fig. 15.8).

2. *Remove the stick.* — Use a clean glove, cloth, or piece of paper and remove the stick from the wire rack. If dry, lightly brush away any dust. Use a clean, soft bristle paint brush. If stick is wet, shake away any free moisture (fig. 15.2).

3. *Weigh the stick.* — Lay the center of the stick across the center of the balance pan (fig. 15.9). Move the two large weights across their respective beams until the pointer swings freely. Be sure that the weights are seated in the notches of the beams. Now adjust the small sliding weight on the front beam until the pointer swings the same distance above and below the zero mark on the small vertical scale at the end of the pointer.

In case the balance is sluggish in its action, always tap the main bearing case with a finger or pencil so that the pointer will not settle prematurely in the wrong place.

Read the scale and record the weight of the stick in excess of 100 grams.

4. *Replace the stick.* — Return the stick to its wire rack making sure same side faces up (brads down) and screw hook pointing north (fig. 15.4).

Move all balance weights to zero.

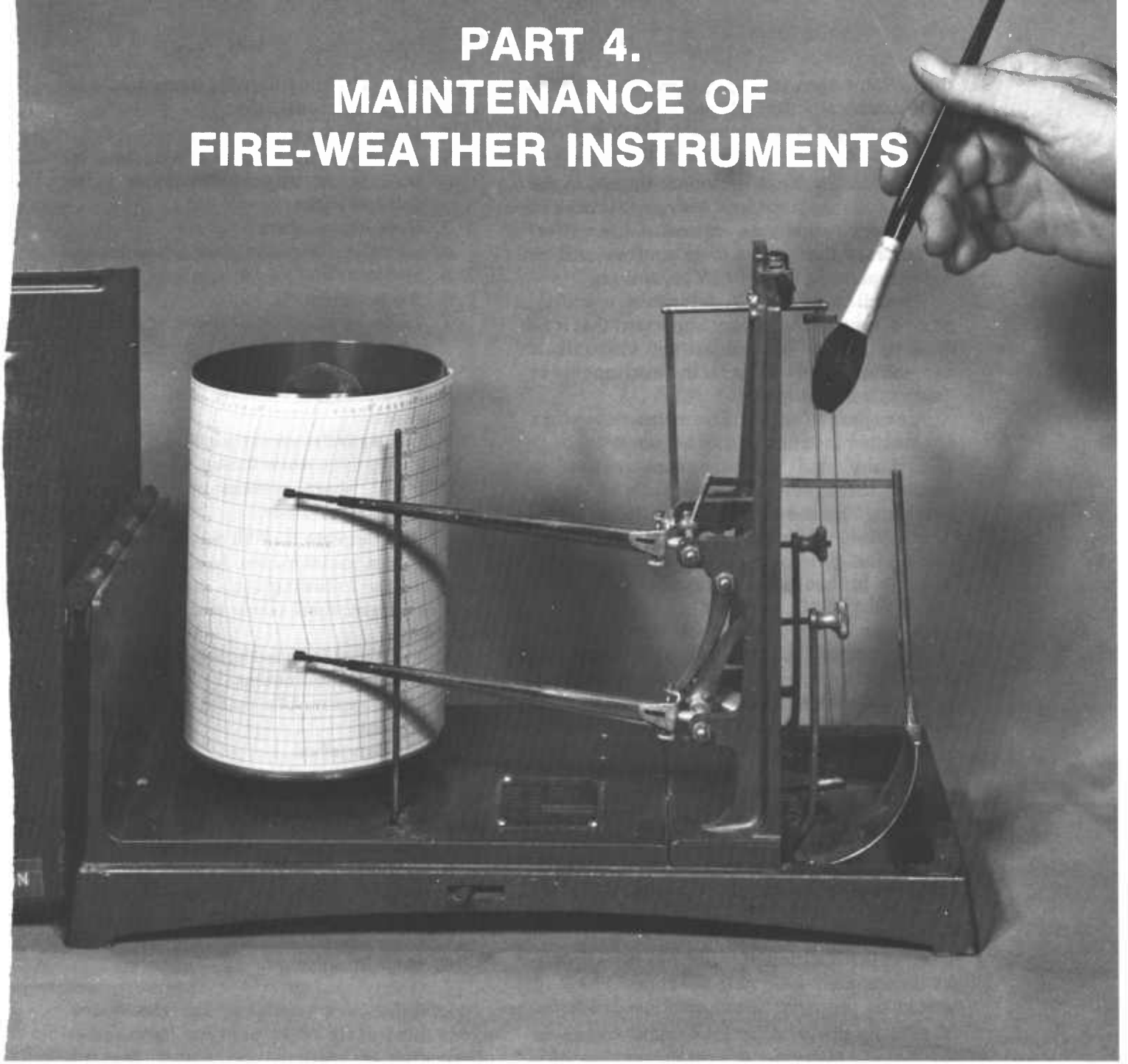
CROSS REFERENCE: Description 5.1, 5.3; Maintenance 23, 24.5

15.5 HARVARD BALANCE

The operation of the double pan Harvard balance is similar to that of the triple beam balance except for the manipulation of the weights. To weigh the stick, place it on one of the pans and add a 100-gram weight to the other pan (fig. 15.10). Now add additional small weights to the pan until the vertical pointer swings freely. Use the sliding weight on the front scale to achieve final balance.

CROSS REFERENCE: Description 5.1, 5.3; Maintenance 23, 24.6.

PART 4. MAINTENANCE OF FIRE-WEATHER INSTRUMENTS



Proper maintenance is the final ingredient for consistently accurate fire-weather observations. It is unreasonable to expect an instrument in poor operating condition to provide acceptable data. It is equally unreasonable to expect an instrument to be in good operating condition when it has not been subjected to a program of continuous maintenance.

The question of whom should do the instrument maintenance job is an important one. Quite often routine daily maintenance will be accomplished by the observer while the more detailed periodic or annual maintenance job will be assigned by a person who is skilled and experienced in the maintenance of instruments. Agencies that have electronic or radio technicians on the staff often assign the bench maintenance of weather measurements to

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them. Some agencies train a fire control technician specifically for the instrument maintenance task and accomplish this work at a central location during the nonfire season months.

If an agency lacks personnel trained in the proper skills they can send instruments back to the factory (usually an expensive alternative) or contract the job to local sources such as watch repairmen or radio-TV repairmen.

Regardless of how maintenance is accomplished, however, it is very important that it be done by people who understand instruments and will not "tinker" with the instruments or "maintain them to death."

A program of continuous maintenance for a fire-weather instrument should include:

1. Daily and periodic maintenance, as needed, throughout the service life of the instrument. This should include routine cleaning, lubrication, calibration checks and adjustments, and prompt repair or replacement of worn or broken parts. This can often be accomplished by the observer.

2. Annual or semiannual inspection and general service. At this time the instrument should be brought to the workbench, taken apart, and closely inspected for signs of wear and tear. This is a job for the trained technician who knows what he is doing. Like most everything else, weather instruments do wear out. Don't try to keep them forever. Replace beat-up, or even obsolete instruments!

3. Following repair or replacement of worn or broken parts, the instrument should be carefully tested to insure that all components are operating properly and that it is precisely calibrated.

4. If the instrument is not put back in service immediately following the annual check, it should be properly stored until needed again.

Like so many other jobs, maintenance of fire-weather instruments is easier and more efficient if the proper tools are readily available. In the case of periodic maintenance, the presence of the right tool or service item at the right time will often determine whether or not it is possible to perform the required maintenance. For this reason, a tool cache should be provided at the fire-weather station. A small, weatherproof box attached to a fencepost or the anemometer pole (fig. 8.11) can easily serve this purpose (see section 8.6). The following items should be included in such a tool cache:

1. Clean wiping cloths.
2. Assorted soft brushes for dusting instruments, hygrothermograph hairs, and fuel sticks.
3. Needle-nose pliers.
4. Small and medium sized screwdrivers.
5. Medium sized carpenter's level.
6. Anemometer oil.
7. Light instrument oil (sewing machine oil, gun oil, etc.).
8. Hygrothermograph ink.
9. Hygrothermograph and rain gage charts.
10. Clean psychrometer wicking.
11. Heavy duty white thread.
12. Small, sharp scissors or single-edged safety razor blade.

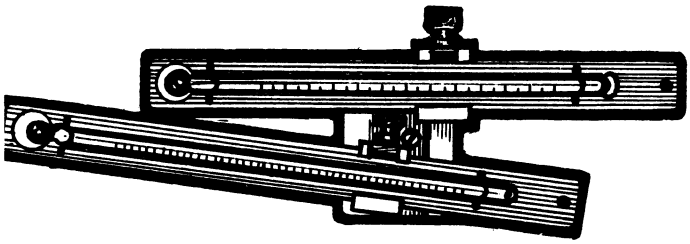
A more complete tool kit is required for annual or bench maintenance. **In addition** to the above list, the following items should be available at an instrument repair and maintenance workbench:

1. Supply of fresh batteries.
2. Extra thermometers.
3. Nonflammable instrument cleaning solvent.
4. Toothbrushes.
5. Continuity tester.
6. Anemometer calibrator.
7. Soldering gun and rosin core solder.
8. Crocus cloth.
9. Special lubricants.
10. Hygrothermograph hair elements.
11. Hygrothermograph and rain gage pens.
12. Lampblack oil color.
13. Hard-finish paper.
14. Compressed air.

Maintenance instructions for the instruments most likely to be used for fire-weather observation are included in the pages that follow. General maintenance instructions that apply to all instruments of a given type as well as specific maintenance instructions for specific makes or models are given.

Although these instructions are set down in a step-by-step fashion, the user is cautioned to read through the entire section of interest before attempting to use the instructions cookbook fashion during actual maintenance.

CHAPTER 16



THERMOMETERS

Care is the byword in maintenance of thermometers, which are very fragile instruments. Whenever possible, handle the thermometer in its mounting plate. Be especially careful not to strike the bulb against anything.

Thermometer maintenance is mainly concerned with cleaning, restoring obscured markings, and the most important task of recognizing and correcting defects.

16.1 CLEANING

The thermometer and its mounting plate should be kept clean. This can be accomplished by regular dustings with a soft brush. Periodically the thermometer should be removed from the mounting plate and both the thermometer and the mounting plate washed with soap and water. Vinegar or a nonflammable cleaning solvent may be used to remove stubborn dust or corrosion provided that the thermometer is subsequently rinsed in clean water.

16.2 RESTORING WORN MARKINGS

Thermometer markings often become obscured over time and are consequently hard to read. Obscured markings can be renewed by spreading a small amount of lampblack oil color on the stem and then immediately rubbing off the excess with a piece of hard-finish paper. Art supply shops and many paint stores carry the lampblack oil color needed to do this job.

16.3 THERMOMETER DEFECTS

Thermometers should be checked periodically for two types of defects (fig. 16.1).

1. Broken constrictions on standard maximum thermometers.
2. Separated alcohol or mercury columns on all thermometers.

Fractured Maximum Thermometers

It was mentioned previously that the maximum thermometer has a constriction in the capillary, just above the bulb. This constriction allows the mercury to expand upward as the temperature rises but does not allow the mercury to retreat into the bulb when the temperature drops. The mercury trapped above the constriction is free to float in the capillary; this is not a defect. Because of this floating tendency, however, the thermometer must be slowly lowered to the vertical position before reading. If the thermometer is abruptly lowered from the horizontal to the vertical position, a floating column might slam down against the constriction to fracture it. The constriction can be similarly damaged during resetting by spinning the thermometer while the column is floating above the constriction.

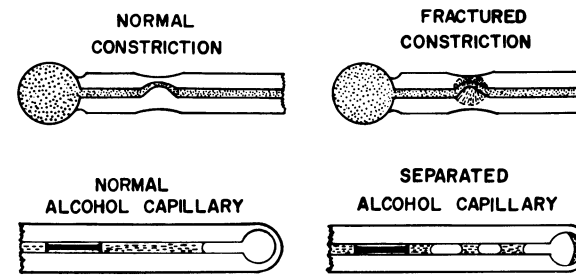


Figure 16.1 — Thermometer defects: *Top*, Normal and fractured constrictions in maximum thermometers; *bottom*, normal and separated alcohol capillaries in minimum thermometers.

The result of a fractured constriction is that the mercury is now able to retreat through the constriction into the bulb. This is a defect and such a thermometer, sometimes called a "retreater," should be replaced.

Fractured constrictions on maximum thermometers are often hard to detect; but these malfunctions should be suspected whenever the maximum temperature consistently reads more than 1° F. lower than the reading on the thermometer when set at the previous observation.

Separated Columns

A separated column is one in which portions of the fluid become separated from the main column. Column separation is common in all thermometers, especially after shipping or other situations where they receive excessive shaking. In alcohol thermometers, column separation may also be caused by the condensation of alcohol vapor in the upper part of the bore.

Separated alcohol and mercury columns can usually be reunited by one of the following procedures:

1. A very quick and easy method is to attach the thermometer, in its mounting plate, to a sling psychrometer handle to which is fastened 1½ feet of chain, wire, or thin nylon rope. Make sure that sufficient clearance exists and then vigorously sling the thermometer as you would a sling psychrometer.

2. Hold thermometer securely in your hand by curling your fingers and thumb around the edges of the mounting plate. Be sure that the bulb end points away from the body. **Do not** touch or press on the glass tube itself, or it may crack during shaking. Shake down with a long sweep, ending abruptly. Make sure you have sufficient clearance from obstructions.

3. Lay out a small cushion of newspapers or magazines, or similar object with some "give." Take thermometer, in its mounting plate, check that all mounting screws are tight, and with bulb end down tap the thermometer lightly. The detached drops should gradually unite with the main column. Do not tap too hard or the small nub at the upper end of the thermometer may break off from the stem. After successfully reuniting the column, let the thermometer stand vertically in a warm place for an hour so that any remaining droplets have a chance to drain down to the main column.

4. As a last resort, heat can be applied to the thermometer bulb. This is best accomplished by holding the thermometer bulb in a pan of water which is being slowly heated. Be sure to remove bulb from water before column reaches top of tube. Remember that the column will continue to rise briefly after removed from the water.

   a. **For an alcohol thermometer,** continue to heat the bulb in the above manner until the main column enters **but does not completely fill** the small air chamber or bulb at the top of the stem. This should drive all the air bubbles up the stem and into the air chamber where they should rise above the alcohol. **Do not let the alcohol completely fill the air chamber** — it can blow the top off the thermometer, or blow out the bulb, depending on which is weaker.

      After all the bubbles have been removed by this method, remove the thermometer from the water and hang it, bulb down, to cool. This will allow any liquid which may have clung to the sides of the bore to drain down into the column.

   b. **If a mercury thermometer** and a small amount of mercury is separated from the top of the main column, heat in the same manner as prescribed above until a small amount of mercury enters the small bulb. Holding this temperature, quickly tap a few times. Remove from water and as the mercury drops see if column is reunited; if not, repeat. **Do not let the mercury completely fill the air chamber as it can blow out the top or bulb of the thermometer.**

      If the amount of mercury above the separation is more than the upper air chamber can hold, a slightly different procedure should be followed. If available, first cool the bulb only in dry ice until all the mercury is in the large lower bulb. Then carefully tap bulb end of the thermometer gently to

bring all bubbles to the top. Now allow bulb to warm slowly.

Specific instructions for maintenance of wet- and dry-bulb thermometers are discussed in chapter 18. Specific instructions for several types of maximum-minimum thermometers follow.

16.4 STANDARD MAXIMUM-MINIMUM THERMOMETERS EQUIPPED WITH TOWNSEND SUPPORT

Refer to figure 16.2.

Annual Maintenance

Thermometers

1. Remove the thermometer retaining strip and screws (E) and lift the thermometers from their mounting plates (D). Be careful not to lose the tiny retaining screws.

2. Use soap and water to clean the thermometers and mounting plates. Remove stubborn dirt or corrosion with instrument cleaning solvent or vinegar.

3. Carefully check thermometers for defects (see section 16.3). Repair or replace as necessary.

4. If markings on thermometers are obscure, renew according to instructions in section 16.2.

5. Secure thermometers in their mounting plates.

Townsend Support

Refer to figure 16.3.

6. Remove the screw (A) holding the spinning clamp (B) to its shaft (D). Slide off spinner (B) from shaft (D).

7. Wash thoroughly with a nonflammable instrument cleaning solvent.

8. Clean out oil hole (C) on spinner.

9. Put a drop of light instrument oil on spinner shaft (D) and replace spinner (B).

Periodic Maintenance

1. Add a drop of oil through the oil hole (C) on the spinner (fig. 16.3) as needed.

2. Check both thermometers for defects, i.e., fractured constrictions, separated column, etc. (see section 16.3).

3. Check thumbscrews (F) on clamps for tightness.

4. Dust thermometers with a soft brush to remove any accumulated dirt.

CROSS REFERENCE: Description 1.1; Installation and Exposure 8.2; Operation 10.1, 10.2.

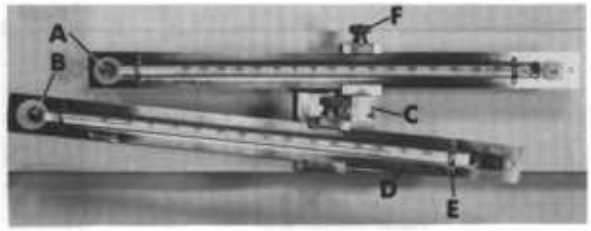


Figure 16.2. — Standard maximum-minimum thermometer mounted in Townsend Support: *A*, Minimum thermometer; *B*, maximum thermometer; *C*, Townsend Support; *D*, thermometer mounting plate; *E*, thermometer retaining strip and screws; *F*, Townsend Support thumbscrew.

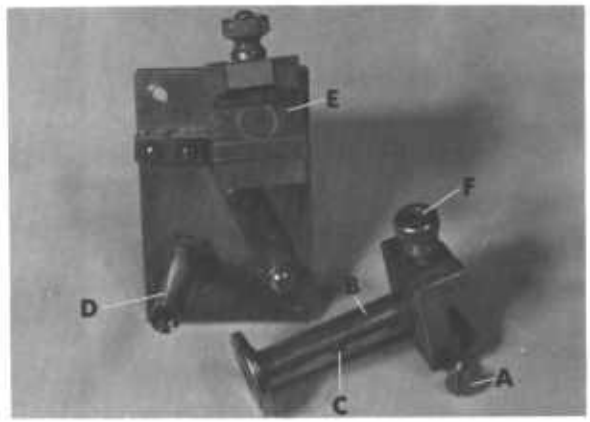


Figure 16.3. — Unassembled Townsend Support: *A*, Spinner clamp retaining screw; *B*, spinning clamp; *C*, oil hole; *D*, spinner shaft; *E*, upper clamp; *F*, thumbscrew.

16.5 COMBINED (SIX'S) MAXIMUM-MINIMUM THERMOMETER

(Taylor, Weksler, and similar models)

Refer to figure 16.4.

Annual Maintenance

1. Remove upper and lower thermometer retaining strips (B) and very carefully lift out the thermometer tube (C).

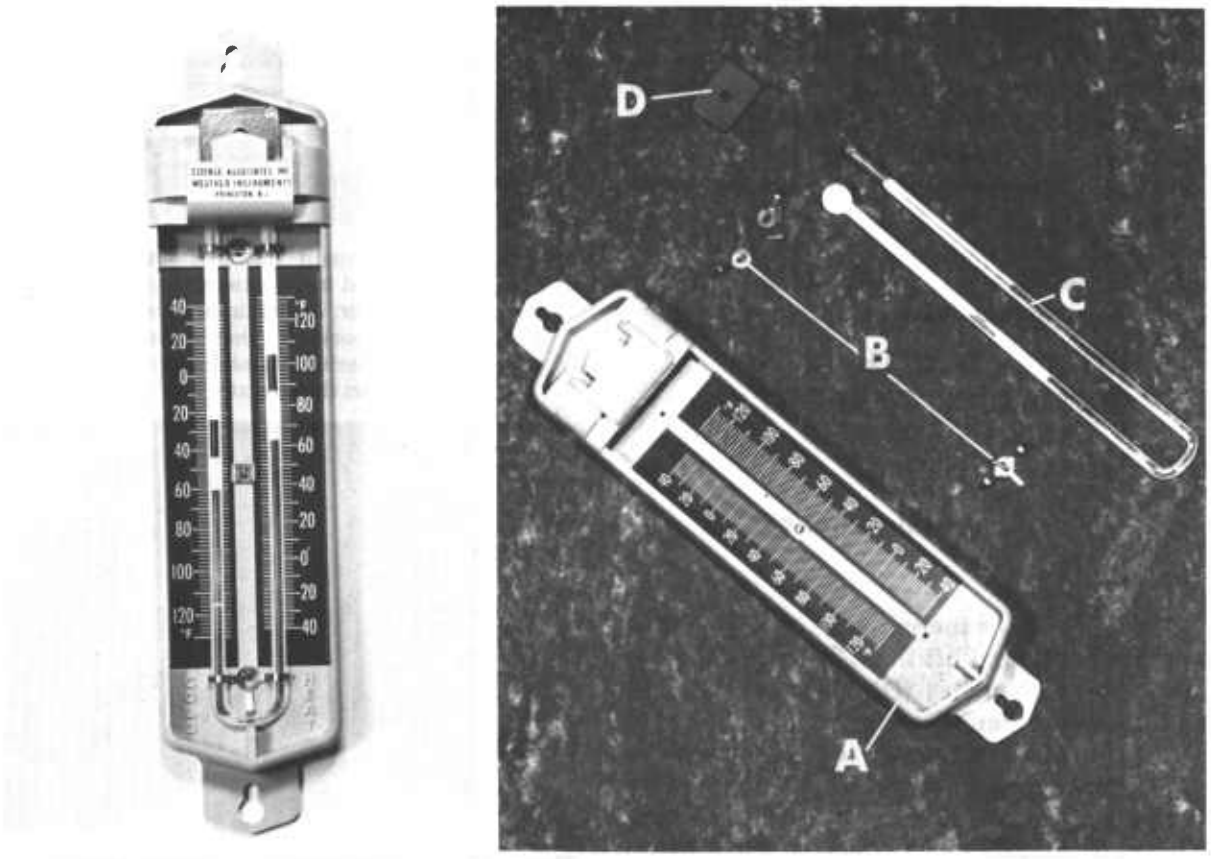


Figure 16.4.— Combined maximum-minimum thermometer; *Left*, Assembled; *right: A*, mounting plate; *B*, thermometer retaining screws and strip; *C*, thermometer tube; *D*, magnet.

2. Clean thermometer and its mounting plate (A) with soap and water. Use instrument cleaning solvent or vinegar to remove stubborn dirt or corrosion from thermometer tube.

3. Return thermometer tube to the mounting plate and secure with the thermometer retaining strips.

4. Inspect thermometer for defects.

   a. If column is separated, grasp the instrument firmly in hand with bottom of "U" tube pointing toward ground. Curl fingers and thumb around mounting plate; do not touch or press on glass tube itself as it may crack during shaking. Now swing hand forcefully downward in an arc. Do this until the columns reunite.

   b. If either of the index rods settles into its mercury column, attempt to correct by the same procedure given above.

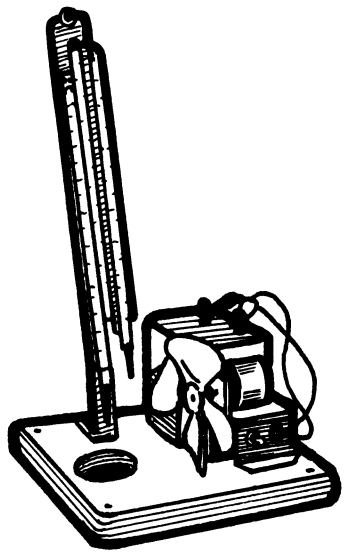
   c. Conduct the following procedures if either index has been forced into either of the expansion chambers (the large bulbs) at the tops of the thermometer tube: First, attempt to draw the index out using the magnet (D). If this doesn't work, gently tap the bulb in order to manipulate the index at least partially into the bore and then draw it all the way into the bore with the magnet.

Periodic Maintenance

1. Check for defects whenever instrument is reset.

2. Dust tube with a soft brush to remove accumulated dirt.

CROSS REFERENCE: Description 1.1; Operation 10.1, 10.3.



PSYCHROMETERS

Psychrometers are rather delicate instruments and as such require careful handling and conscientious maintenance. Maintenance consists primarily of regular wick replacement, regular cleaning, periodic lubrication on electrical units, and repair or replacement of worn parts as necessary. Psychrometer maintenance should be continuous while the instrument is in use. Annual maintenance is simply that part of this continuous maintenance when general refurbishing and a more thorough cleaning and lubrication are performed.

17.1 THE WET-BULB WICK

The most serious deficiency in psychrometer maintenance is failure to replace the wet-bulb wick before it gets dirty; unfortunately this is also the most common oversight. A clean wick is essential for accurate wet-bulb readings and should be replaced at the **first sign** of dirt, crust, or discoloration **but at least every 2 weeks** regardless of how clean it may appear. **Only clean, distilled water or other clean, mineral-free water should be used to wet the wet-bulb wick.**

Procedure for replacing a psychrometer wick (fig. 17.1):

1. Remove the old wick using a razor blade or fine-point knife or scissors.
2. Wash hands with soap and water. Rinse thoroughly in clean water.
3. Cut a 3- to 3½-inch length of clean wicking.
4. To remove sizing, wash the new wick in distilled or other mineral-free water.
5. Clean the lower part of the stem and the bulb of the wet-bulb thermometer. Then wash with vinegar to remove stubborn mineral deposit and rinse in clean water.
6. Slip the new wick over the wet bulb to a point on the stem just below the lowest graduation on the stem, about 1 inch above the top of the bulb.
7. Using an extra strength white sewing thread, tie the wick to the thermometer as follows (fig. 17.1):
   a. First, tie wick near the upper end, about 1 inch above the top of the bulb.
   b. Second, tie wick in the middle, immediately above the top of the bulb. Be sure to stretch the wick downward

Figure 17.1. — A properly installed psychrometer wick.

as the knot is tightened to assure a snug fit against the thermometer stem.

c. Third, tie wick immediately below the end of the bulb. To insure a snug fit, make a loop of thread to form a knot and slip it up around the tip of the bulb, just where it begins to round off. Carefully draw the knot tight causing the loop to slip off the tip of the bulb, thereby stretching the wick snugly against the thermometer bulb and at the same time securing it firmly.

d. Using a razor blade or fine-point knife or scissors, trim loose ends of knots as well as all wicking in excess of 1 inch below lower tip of the wet bulb.

If temporarily out of clean wicking, the dirty wick can be removed, washed in soap and water, rinsed thoroughly in clean distilled or other mineral-free water, and replaced. One or two wraps of clean gauze bandage, neatly tied over the bulb, can also serve as a temporary measure. White shoelaces, rinsed in clean distilled water, can also be a satisfactory substitute.

17.2 WET- AND DRY-BULB THERMOMETERS

Maintain wet- and dry-bulb thermometers in accordance with the instructions in sections 16.1 through 16.3. An important item of psychrometer maintenance is assuring that the thermometers agree within one-half graduation when both are read as a dry bulb. For example, if the thermometers have 1° F. graduations, they should read within 1/2° F. of each other when read prior to wetting the wet-bulb wick.

When replacing a broken thermometer on a psychrometer, be sure the replacement matches exactly the accuracy of the unbroken mate. To insure identical accuracy, it is usually necessary to replace both thermometers with a new matching pair. When replacing thermometers remember the wet bulb always hangs below the dry bulb. Make sure you put the wick on the bulb that hangs the lowest. This minimizes the chance of moving moist air across the dry bulb during ventilation.

17.3 CLEANING

Psychrometers, especially those constantly exposed in instrument shelters, require regular cleaning. Cleaning can be accomplished by using a camel's hair or other soft bristle brush to remove accumulated dust before each use of the psychrometer.

Specific maintenance instructions for psychrometers commonly used for fire-weather observations follow.

17.4 ELECTRIC FAN PSYCHROMETER

(Forester Model 9X060 and Weather Measure Model HM20)

Refer to figure 17.2.

Annual Maintenance

1. Remove spacer screw (K) and lift thermometer mounting plate (A) from the support bracket (F). Carefully remove thermometers from the mounting plate. Be careful not to lose the tiny retaining screws. Inspect thermometers according to the instructions of sec-

tions 17.2 and 17.3 and repair or replace as necessary.

2. Remove and discard wet-bulb wick (E) and carefully clean both thermometers and the mounting plate (A). Use a nonflammable cleaning solvent or vinegar to remove stubborn dirt and corrosion. Rinse with clean water.

3. If necessary, renew thermometer markings according to instructions in section 16.2.

4. Carefully replace thermometers in mounting plate. Be sure they are firmly mounted.

5. Install a clean wick on the wet bulb (C) following the procedures in section 17.1.

6. Clean the motor (H) and fan (G), but do not attempt to disassemble the motor.

7. Apply a drop of oil to the fan shaft bearings (G) and wipe off excess. Use anemometer oil or other light, nongumming instrument oil such as sewing machine oil.

8. Check and, if loose, tighten all mounting screws, fan hub setscrew, and electrical connections.

9. Install a fresh 6-volt lantern battery. Turn motor "on" and check to see if fan is blowing air across the thermometer bulbs (away from the fan). If the air is being sucked into the fan, reverse the connecting wire leads on the battery.

10. On motor units with a thrust plate, check for proper adjustment of the thrust plate (I). Turn the motor "on" and carefully bend the thrust plate to the point where the greatest r.p.m. is realized.

11. If the fan will not operate, check the battery, the electrical connections, and the switch. If trouble is not apparent, replace the motor.

12. If instrument is not to be put in immediate service, disconnect the battery from the motor.

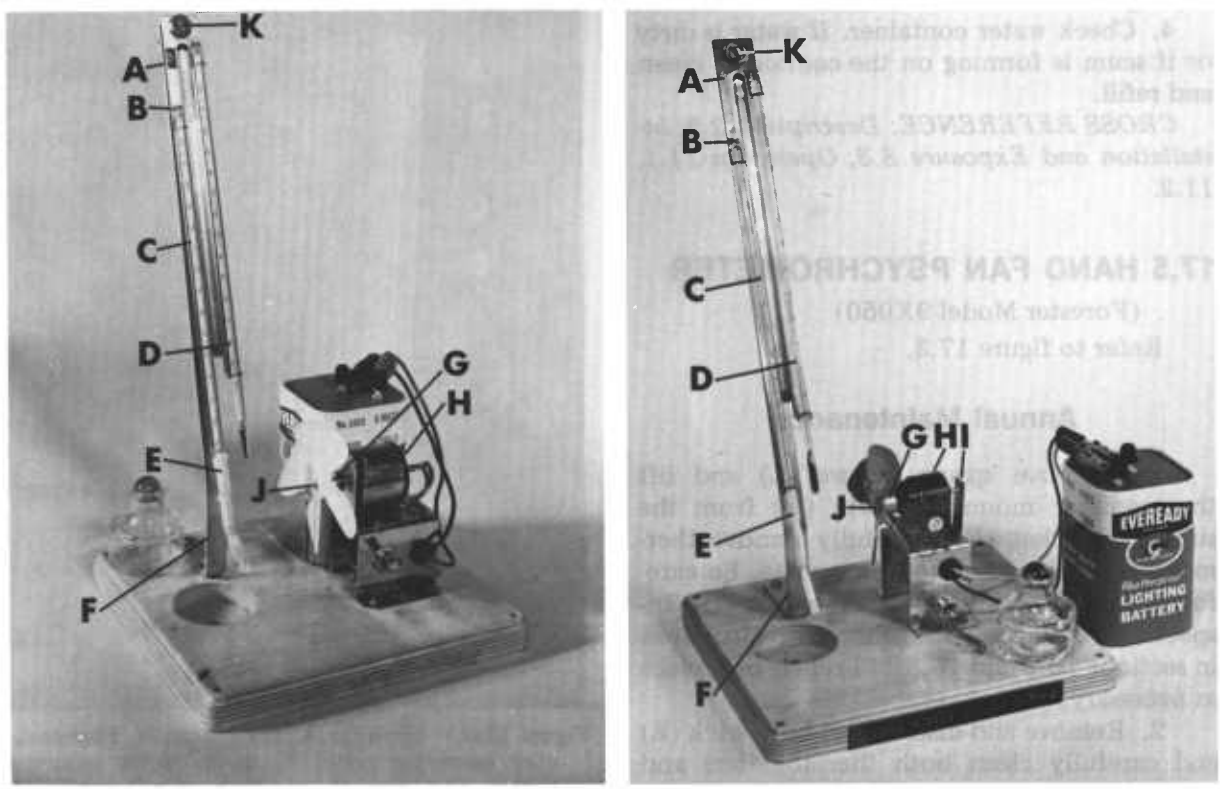


Figure 17.2. — Forester 9X060 electric fan psychrometer *(left)* and Forest Service electric fan psychrometer *(right)*: *A*, Thermometer mounting plate; *B*, thermometer retaining screws and clip; *C*, wet-bulb thermometer; *D*, dry-bulb thermometer; *E*, wet-bulb wick; *F*, support bracket; *G*, fan and shaft; *H*, motor; *I*, thrust plate; *J*, fan bushing; *K*, spacer screw.

Periodic Maintenance While in Use

Maintenance At Least Every 2 Weeks

1. Replace wet-bulb wick (see section 17.1).
2. Remove all dust with a camel's hair brush.
3. Oil the fan shaft bearings if necessary.
4. Check all screws and tighten if loose.
5. Check battery and replace at first sign of weakness. (A 6-volt lantern battery may last up to 6 months with once-a-day use.)
6. Check water container and clean if dirty or if scum is forming on side.

Daily Maintenance

Before Each Use

1. Brush off any dust or dirt that may have accumulated since last use.
2. Check to see that thermometers agree within 1/2° F. when both are read as dry bulbs.
3. Check the wick and replace it if there is any sign of dirt or discoloration.
4. Check water container. If water is dirty or if scum is forming on the container, clean and refill.

CROSS REFERENCE: Description 2.2; Installation and Exposure 8.3; Operation 11.1, 11.2.

17.5 HAND FAN PSYCHROMETER

(Forester Model 9X050)

Refer to figure 17.3.

Annual Maintenance

1. Remove spacer screws (L) and lift thermometer mounting plate (A) from the support bracket (F). Carefully remove thermometers from the mounting plate. Be careful not to lose tiny retaining screws (B). Inspect thermometers according to instructions in sections 16.2 and 16.3 and repair or replace as necessary.

2. Remove and discard wet-bulb wick (E) and carefully clean both thermometers and the mounting plate (A). Use a nonflammable cleaning solvent or vinegar to remove stubborn dirt and corrosion. Rinse with clean water.

3. If necessary, renew the thermometer markings according to instructions in section 16.2.

4. Carefully replace thermometers in mounting plate. Be sure they are firmly mounted.

5. Install a clean wick on the wet bulb following the procedures in section 17.1.

6. Clean the fan unit.

7. Oil the crank shaft (M) with a drop of oil in the hole (N) on top of the bearing.

8. Put a drop of oil on the fan shaft. To gain access to this shaft, spring its supporting strap steel away from the drive wheel (I) and slip the fan (G) off.

9. Inspect for slippage between the drive wheel and the hub of the fan shaft. If there is too much slippage, increase tension by tightening the tension screw or bending the fan support.

10. Inspect the hub of the fan shaft. If the hub is badly worn, remove the fan blade and

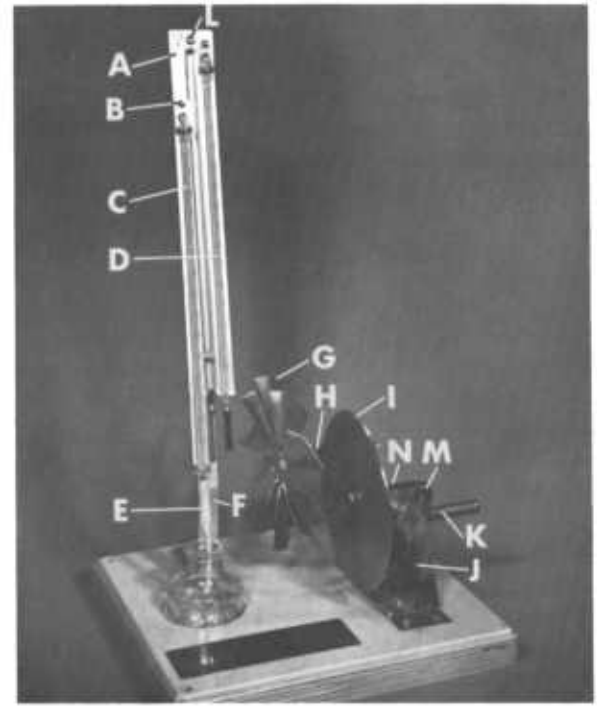


Figure 17.3. — Hand fan psychrometer: *A*, Thermometer mounting plate; *B*, thermometer retaining screw and clip; *C*, wet-bulb thermometer; *D*, dry-bulb thermometer; *E*, wet-bulb wick; *F*, support bracket; *G*, fan and shaft; *H*, fan pulley; *I*, drive wheel; *J*, fan pedestal; *K*, crank; *L*, spacer screw; *M*, crankshaft; *N*, oil hole.

hub. Turn the hub over and replace it and the fan blade. This will allow the drive wheel to engage the unworn groove in the fan shaft hub.

Periodic Maintenance

Maintenance At Least Every 2 Weeks

1. Replace wet-bulb wick (see section 17.1).
2. Remove all dust with a camel's hair brush.
3. Put a drop of oil on the crankshaft and a drop on the fan shaft.
4. Tighten all screws. Make sure unit is firmly mounted to floor of instrument shelter.
5. Check water container. If water is dirty or if scum is forming on the container, clean and refill.

Daily Maintenance

Before Each Use

1. Brush off dust and dirt.
2. Check to see that thermometers agree within 1/2° F. when both are read as dry bulbs.
3. Check the wick and replace it if there is any sign of dirt or discoloration.
4. Check water container. If water is dirty or if scum is forming on the container, clean and refill.

CROSS REFERENCE: Description 2.2; Operation 1.1, 11.4.

17.6 PORTABLE ELECTRIC FAN PSYCHROMETER

(Bendix Psychron Model 566 and Gemware Model Electro V)

Refer to figure 17.4.

Periodic Maintenance

The timing and extent of maintenance on portable electric psychrometers depends on the type and amount of use.

Cleaning should be a continuous maintenance item and lubrication should be done at least monthly if the instrument receives daily use. The wick should be changed at the first sign of dirt or discoloration but at least every 2 weeks while in regular use.

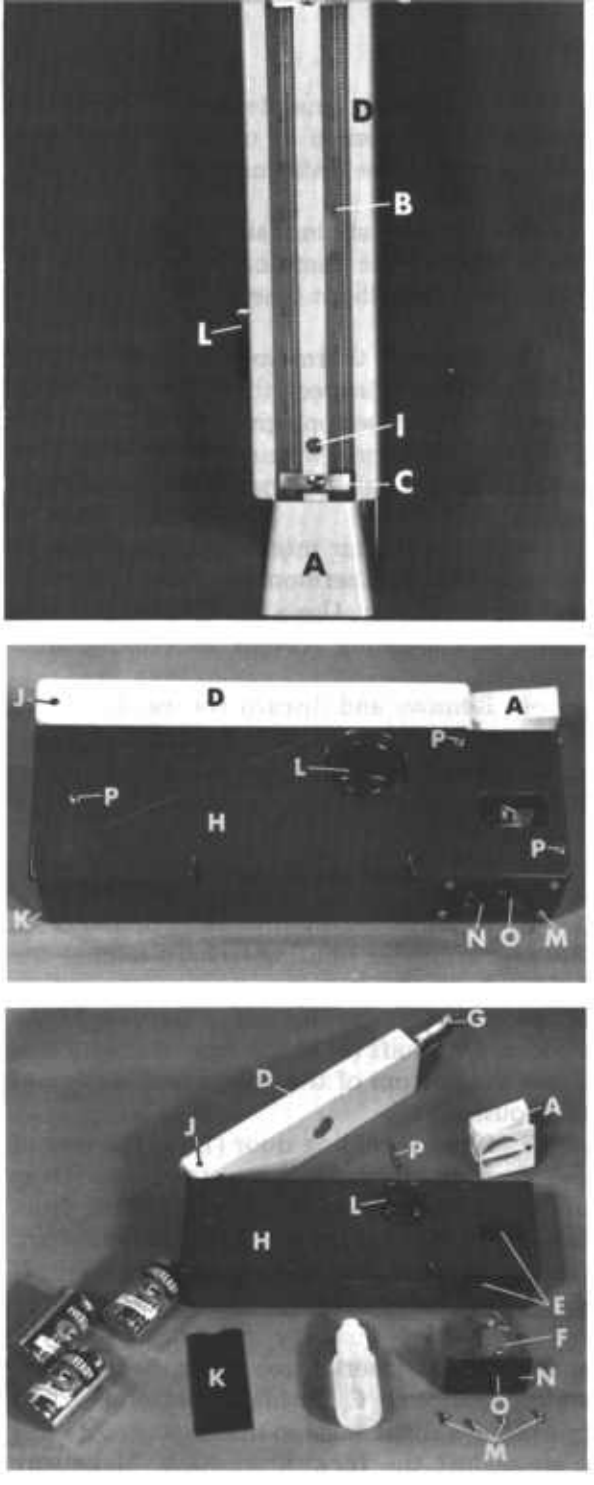


Figure 17.4. — Portable electric fan psychrometers: *A*, Air intake; *B*, dry-bulb thermometer; *C*, retaining strip; *D*, thermometer holder; *E*, air intake cylinder; *F*, fan and motor; *G*, wet-bulb thermometer and wick; *H*, psychrometer housing; *I*, retaining screw; *J*, thermometer holder shaft; *K*, sliding door; *L*, switch; *M*, motor mounting screws; *N*, motor mounting plate; *O*, fan shaft; *P*, housing screws.

The following maintenance instructions should be performed as needed but at least once a year if the instrument receives regular use.

1. Remove sliding air intake (A) and, while holding the thermometers in place, remove the two thermometer retaining strips (C).

2. Lift the thermometers out of their holder (D) and inspect them for defects according to instructions given in section 17.2. Make sure both agree within 1/2° F. when both are read as dry bulbs. Repair or replace as necessary.

3. Clean the air intake (A), the air intake cylinder (E), the thermometer holder, the fan, and the fan motor. Use a small brush and nonflammable cleaning solvent to remove stubborn dirt.

4. Remove and discard the wet-bulb wick (G). Carefully clean both thermometers. Use a nonflammable cleaning solvent or vinegar to remove stubborn dirt or corrosion. Rinse with clean water.

5. If necessary, renew thermometer markings according to instructions in section 16.2.

6. Remove the thermometer holder from the psychrometer housing (H). To remove the holder from the housing, remove the screws (I) on top of the holder and in the case of the Bendix, the shaft (J) at the rear of the holder. Clean the bottom of the holder and the top of the housing.

7. Remove sliding door (K) at the rear of the housing. Remove the water bottle from upper compartment and the batteries from the lower compartment. Remove the hard paper liner from the battery compartment. If dirty, clean or replace.

8. Replace battery compartment liner and carefully insert three fresh, heavy-duty, waterproof, size C flashlight batteries. Hold housing at a slight angle so that batteries do not slam against the forward contact. Make sure that batteries are inserted so that the center tips are forward.

9. Put one drop of oil on the bottom end of the fan shaft (0). Put one drop of oil on the fan shaft between the motor and the fan blade.

10. Turn switch (L) "on" and check lamp on top of housing. Replace lamp if necessary.

11. Turn switch "on" and check fan operation. If fan is rubbing against cylinder walls, turn switch "off," loosen the screws (M) on the motor mounting plate (N) on the bottom of the housing. Insert fingers into fan cylinder and reposition the motor so that the fan blades clear the cylinder wall.

12. Reattach thermometer holder on top of housing.

13. Replace thermometers in thermometer holder. Be sure retaining strips are tight.

14. Install a new wick on the wet bulb (see section 17.1).

15. Clean the water bottle and fill with clean, distilled, or other mineral-free water.

Troubleshooting

1. If switch is "on" but light doesn't operate, replace lamp on top of housing (see item 10, above).

2. If switch is "on" and light is very dim, replace batteries (see item 8, above).

3. If switch is "on" and lamp is lit but fan does not operate, check to see if fan is hung up on cylinder wall (see item 11, above).

4. Further troubleshooting requires complete disassembly of the instrument as follows:

   a. Remove sliding air intake (A).
   b. Remove thermometer holder (D) from housing (H).
   c. Remove sliding door (K) from rear of housing.
   d. Remove screws (M) from motor mounting plate (N) on bottom of housing.
   e. Remove screws from side of housing and carefully pull apart the halves of the housing.

5. Check all contacts and electrical connections. Use crocus cloth to remove any corrosion. Bend distorted contacts back into shape. Resolder any loose connections.

6. If neither the lamp nor the motor operate after following the previous instructions, replace the switch.

7. If, after checking and repairing contacts and connections, the lamp works but not the fan, replace the motor.

CROSS REFERENCE: Description 2.2; Operation 11.1, 11.3.

17.7 MORTARBOARD PSYCHROMETER

(Southern Forest Fire Laboratory Model)

Refer to figure 17.5.

The mortarboard psychrometer was designed for easy maintenance. Regular cleaning, wick changes, and thermometer maintenance are the main items of concern. Maintenance should be conducted throughout the service life of the instrument.

Thermometers

1. Follow instructions for thermometer maintenance in section 17.2.

2. At least every 2 weeks (or when wick is changed), inspect thermometers to see if they agree within 1/2° F. when both are read as dry bulbs. If they do not, repair or replace with a new matched set.

3. Inspect thermometer bulbs for dirt and mineral deposit at each wick changing. Remove stubborn dirt with a nonflammable cleaning solvent or vinegar.

Water Cup

1. Inspect the cap (K) and the tubing (J). The cap should fit tightly on cup (L) and tubing should extend from just above bottom of cup to 1 inch below tip of wet bulb (F).

2. Wash cup and tube in clean water each time a fresh supply of wicking (I) is installed.

3. Do not allow the water level in cup to drop below half full.

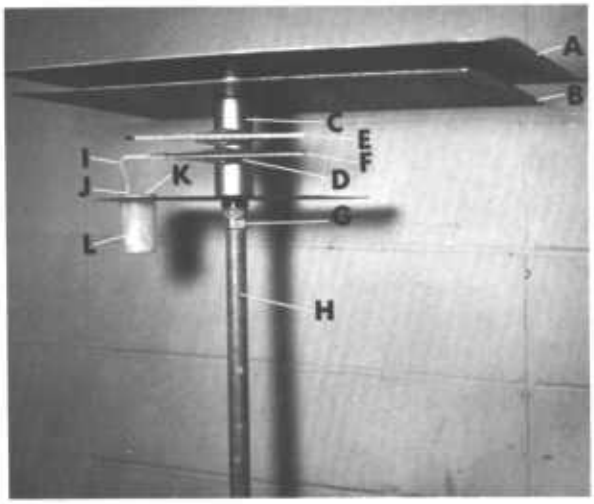


Figure 17.5. — Mortarboard psychrometer: *A*, Upper radiation shield; *B*, lower radiation shield; *C*, spacer; *D*, thermometer clip; *E*, dry-bulb thermometer; *F*, wet-bulb thermometer; *G*, connectors and couplings; *H*, support; *I*, wet-bulb wick; *J*, plastic tubing; *K*, water cup cap; *L*, water cup.

Wet-Bulb Wick

Wicking is installed in 28-inch lengths with the excess coiled in bottom of water cup. Wick changes are made from this supply as long as the supply of wicking in the water cup touches bottom of water cup.

The procedure for installing and changing the wick is as follows:

1. Before installing a fresh length of wicking (I):
   a. Remove old wick.
   b. Clean water cup (L) and tubing (J).
   c. Clean thermometers.
2. Wash hands and rinse thoroughly.
3. Coil a 28-inch length of fresh wicking and place in bottom of water cup.
4. Pull end of fresh wicking (I) through water cup cap (K) and tubing (J).
5. Slip end of fresh wicking over the wet bulb (F) to a point 1 inch up the stem. Be sure there are no snags in wick between cup (L) and wet bulb.
6. The portion of wick covering the wet bulb should be changed whenever it gets dirty or discolored but at least every 2 weeks.
7. To change the wick, cut off exposed portion of wicking halfway between end of tube and wet bulb. Remove old wicking from bulb and discard.
8. Pull up a length of fresh wicking out of the water cup and slip it over the wet bulb to a point 1 inch up the stem.
9. When supply of wick in water cup no longer reaches the bottom of the cup, install a new length of wicking.

Reflective Surface

1. Keep the top surface of the upper radiation shield (A) clean at all times and polish it periodically (about three or four times a year).

CROSS REFERENCE: Description 2.2; Operation 11.1, 11.7.

17.8 SLING PSYCHROMETERS

(Standard and pocket models)

Refer to figure 17.6.

Annual Maintenance

1. Remove retaining clips (A) and lift thermometers from mounting plate (B). Remove wick (E) from the wet bulb (D) and discard. Maintain thermometers according to instructions in section 17.2.

2. Clean mounting plate (B). Use nonflammable instrument cleaning solvent to remove stubborn dirt and corrosion.

3. Inspect the spinning or whirling mechanism (F and G) for wear. Chain links, swivels, and hooks are very susceptible to wear. Repair or replace worn parts.

4. Tighten all screws.

5. Oil shaft or other spinning parts.

6. Replace thermometers, making sure that they are securely mounted in holder.

7. Install a fresh wick following procedure in section 17.1. Be sure wick is tied securely to wet bulb.

Periodic Maintenance

1. Change the wick at least every 2 weeks if instrument is used daily. If used irregularly, change the wick at first sign of dirt or discoloration. Pocket sling psychrometers often require frequent wick changes because the instrument is usually slipped into a case immediately after each use and the wet wick rubs against inside of case and thus becomes discolored.

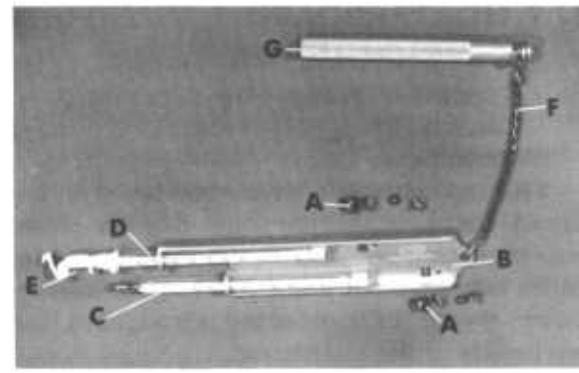


Figure 17.6. — Sling psychrometers: *A*, Thermometer retaining clip; *B*, mounting plate; *C*, dry-bulb thermometer; *D*, wet-bulb thermometer; *E*, wet-bulb wick; *F*, sling chain; *G*, sling handle.

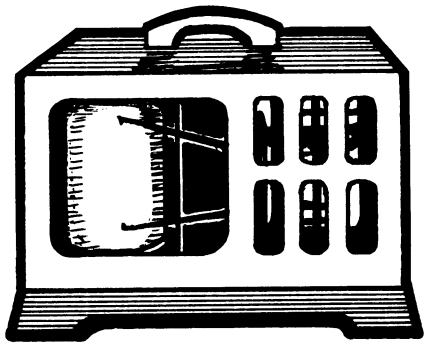
2. Always inspect spinning or whirling mechanism for signs of wear before each use.

3. Store uncased psychrometers out of direct sunlight and in a clean location. Damage to the thermometers is less likely if the instrument is hung up rather than laid down.

CROSS REFERENCE: Description 2.2; Operation 11.1, 11.5.

CHAPTER 18

HYGROTHERMOGRAPHS



Because the hygrothermograph is a rather delicate instrument, the reliability of its data depends to a large extent on the level of maintenance. Due to certain inherent characteristics of its sensors, large errors can occasionally occur despite the best efforts of the observer. These errors can be minimized, however, through continuous general maintenance and periodic calibration checks. Carefully service hygrothermographs and recalibrate as necessary: (1) prior to each period of use, (2) after changing the hair element, and (3) whenever loss of calibration occurs during use.

The following tools and supplies are required for efficient hygrothermograph maintenance: needle-nose pliers, small screwdriver, small monkey wrench, camel's hair brush, crocus cloth, and a clean wiping cloth.

Do not attempt temperature and relative humidity calibration unless the hygrothermograph is in good mechanical condition. The observer should be familiar with service requirements contained in the instrument's manual. Additional copies of these manuals are usually available from the manufacturer.

General maintenance items that apply to most hygrothermographs are discussed below. Refer to instrument manuals for details. Components of three popular hygrothermograph models are shown in figures 18.1, 18.2, and 18.3. Reference letters used throughout this chapter refer to figures 18.1, 18.2, and 18.3 unless otherwise specified.

18.1 CLEANING

Keep the instrument clean. Dirt and dust can cause binding of the moving parts. Remove loose dust with a small camel's hair brush. Brush lightly with instrument cleaning solvent to remove hardened dirt. Do not oil except as directed. Usually only the clock need be oiled and this is best done by a clock repairman. Avoid getting oil or solvent on the hairs. If dusty, carefully brush hairs with soft, clean camel's hair brush (fig. 12.4). **Do not** use cleaning solvent on hairs. If extremely dusty, wash the hairs with clean, mineral-free water of air temperature, using a soft, clean camel's hair brush. Replace hairs about every 2 years. Always keep in mind that hygrothermograph parts are delicate and are easily damaged by rough handling.

18.2 PEN ARM ASSEMBLIES

Allow just enough pen pressure on the recording chart to obtain a sharp and continuous trace. Pen pressure can be adjusted by carefully bending the pen arm. The pens must be sharp and clean. If the trace is too broad, draw a piece of chart paper through the points to clean out any dirt or congested ink. If the pen is clogged with dried ink, remove and wash in warm soapy water. Remove pen by gently pulling it straight off the arm. Re-

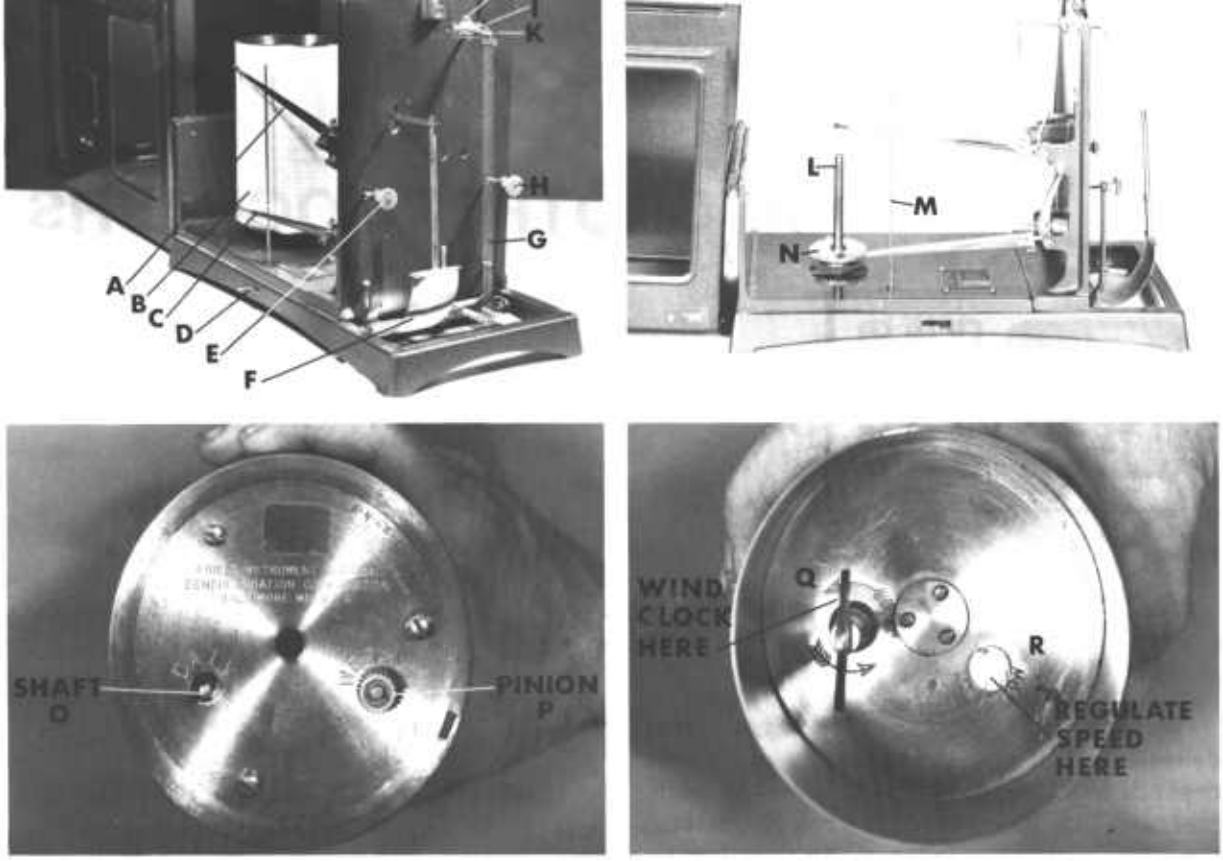


Figure 18.1. — Bendix hygrothermograph. This hygrothermograph is of the clock-in-drum type. Components are: *A*, Temperature pen arm; *B*, chart and chart drum; *C*, relative humidity pen arm; *D*, pen arm shifting rod lever; *E*, temperature pen adjustment knob; *F*, Bourdon tube (temperature sensor); *G*, banjo spread hair element (relative humidity sensor); *H*, relative humidity pen adjustment knob; *I*, magnification bar; *J*, swivel hub and swivel hub setscrew; *K*, pivot pin; *L*, arbor or spindle; *M*, pen arm shifting rod; *N*, arbor or spindle (drive) gear; *O*, pinion shaft; *P*, pinion gear; *Q*, clock winding key; *R*, clock speed regulator.

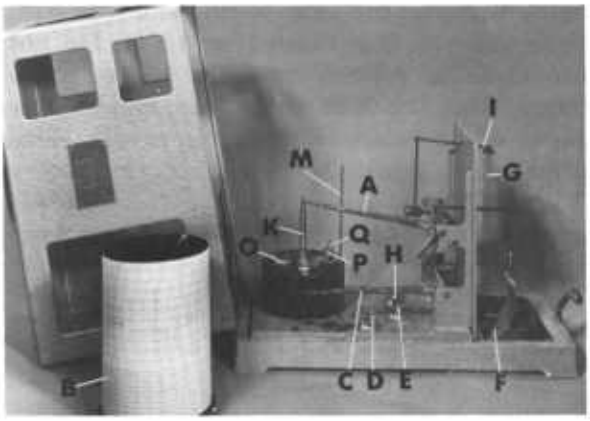


Figure 18.2. — Belfort hygrothermograph. This clock is mounted to the base in this instrument. Components are: *A*, Temperature pen arm; *B*, chart and chart drum; *C*, relative humidity pen arm; *D*, pen arm shifting rod lever; *E*, temperature pen adjustment knob; *F*, Bourdon tube (temperature sensor); *G*, banjo spread hair element (relative humidity sensor); *H*, relative humidity pen adjustment knob; *I*, magnification bar; *K*, arbor or spindle; *M*, pen arm shifting rod; *O*, pinion shaft; *P*, pinion gear; *Q*, clock winding key.

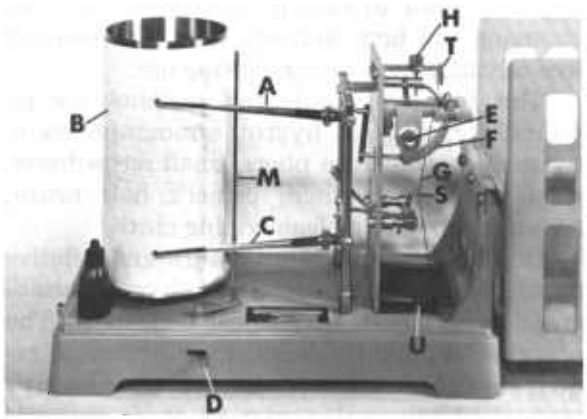


Figure 18.3. — Weather Measure hygrothermograph. This hygrothermograph has a battery-operated clock in the chart drum. Components are: *A*, Temperature pen arm; *B*, chart and chart drum; *C*, relative humidity pen arm; *D*, pen arm shifting rod lever; *E*, temperature pen adjustment knob; *F*, bimetal strip (temperature sensor); *G*, hair bundle (relative humidity sensor); *H*, relative humidity pen adjustment knob; *M*, pen arm shifting rod; *S*, hooked magnification lever; *T*, upper hair jaw; *U*, lower hair jaw.

place by sliding it back on the arm and gently crimping shoulders with a pliers.

If, after cleaning, the pen still makes too broad a trace, sharpen the pen point. Use a point file or a fine mill file to sharpen the pen point until light will not reflect off its nibs. Do not make the pen too sharp or it will cut the chart paper.

If pen fails to ink properly after cleaning or sharpening, replace it with a new one.

After proper inking is insured, see if both pens indicate the same time on the chart. If not, adjust one of them by changing its position on the pen arm. Make sure pens are attached firmly enough so that they do not slide out of position while in use.

18.3 CHART DRIVE ASSEMBLY

Remove all dirt and rust from spindle (L) and gears. Lubrication of the spindle is often recommended to prevent rust; however, too much lubrication encourages the accumulation of dirt. It is often better instead to shine the spindle with crocus cloth and minimize the chance of dirt accumulation. Make sure spindle is straight and that spindle and gears are securely fastened.

Backlash can be a problem on some models with clocks contained in the drum (fig. 18.1). To check for backlash, lift pens from chart and turn drum lightly back and forth. The amount of play should cause an audible click between the gears, but not enough to cause more than 1/2 hour's backlash on a weekly chart. Try this at several points around the clock. If there is either no backlash or too much backlash, adjustment is needed. Remove drum from the spindle and loosen the three screws equally spaced on bottom of drum (fig. 18.4). Shift gear away from center of the drum, tighten the screws, and check again for backlash. Continue this procedure until, through trial and error, you obtain uniform backlash of an acceptable level.

The clock drive gear may mesh too tightly with the large stationary gear (N) at bottom of spindle (L) or inside chart drum (B), causing the clock to either stop or lose time. To test for such a case, remove drum from spindle; if the clock then operates normally, the gears are meshing too tightly. A bent spindle can cause a backlash on one side of the clock and a drag on the other side. Replace a bent spindle.

If there is a drag between gears on clock-in-drum models, remove drum from spindle and very slightly loosen the three screws on bottom of drum (fig. 18.4). Now, move pinion gear (P) away from center of drum. A very slight movement will usually be sufficient.

Tighten the screws, replace drum on spindle, and test for amount of backlash.

18.4 CLOCK

Check clock by comparing rate of drum revolution with chart time scale. If necessary, use the regulator (R) provided to adjust clock time. Move pointer of regulator toward "S" if clock is running fast, or toward "F" if it is running slow. Have the clock overhauled by a competent watch repairman if it does not respond to above regulation. It is good practice

Figure 18.4. — Loosen three screws on bottom of drum and shift gear away from center of drum to correct for backlash and drag between gears.

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to have the clock cleaned and adjusted by a competent watch repairman annually. When this is done, provide the repairman with the instrument manual as it contains needed information on lubrication and timing specifications. If the instrument manual is not readily available, the following information on clock lubrication and timing requirements for the two most common hygrothermographs will be of value.

Bendix-Friez, Model 594 Series

Timing of the escapement. — 18,045 beats per hour.

Mainspring lubrication. — Use a mixture of one part oil, Elgin M-56A or Bendix-Friez oil Part No. 502763, to three parts flake or powdered graphite by volume.

Drive mechanism pivots. — These may be lubricated with the oils listed above but without the graphite added.

Belfort, Catalog No. 5-594

Timing of the escapement. — Nine seconds per hour (45 beats per hour) fast.

Mainspring lubrication. — Use Belfort Instrument Oil No. 5660 for warm weather operation. For cold temperature operation (0° and below), drain oil from mainspring barrel and relubricate with fine powdered graphite or molybdenum disulfide (molykote).

Mechanism gear train lubrication. — For cold temperature operation use Belfort Instrument oil No. 5586.

18.5 CALIBRATION

Hygrothermograph calibration consists primarily of adjustments for zero and for range or spread. Zero refers to the temperature and relative humidity indicated by the position of the pens on the chart in relation to the actual temperature and relative humidity of the surrounding air as measured with wet- and dry-bulb thermometers. Range, or spread, refers to the distance the pen arms travel between maximum and minimum chart values. Although instrument manuals contain fairly complete information on hygrothermograph maintenance, they are usually quite deficient regarding calibration procedures.

18.6 ZERO ADJUSTMENT

Temperature Pen

Perform zero shift adjustment calibration checks only when air temperature is holding steady. Attempts to check calibration during periods of changing temperature are usually unprofitable due to the lag in reaction time of the temperature-sensitive element.

Compare chart temperature indicated by the pen to temperature indicated by a dry-bulb thermometer (unventilated), or a minimum thermometer (read top of alcohol column). If chart temperature varies more than 2° F. from thermometer reading, adjust the pen accordingly. Adjust pen either up or down by turning the knurled thumbscrew (E) connected to the temperature element (F). Briefly lift pen off the chart during adjustment to eliminate any effects of surface friction between pen and chart.

Relative Humidity Pen

The shifting of zero is a major source of error for relative humidity data collected with hygrothermographs. Depending on its direction, zero shift will result in recorded humidities that are either higher or lower than those actually occurring. It is most likely to accompany changes in weather. During range or spread calibration, the hair element is normally exposed to saturated air conditions which results in a low zero position. Exposure of the hairs to prolonged dry weather may then cause an upward shift of the zero. Subsequent exposure to saturated air will often result in a downward shift, often back to the original calibration position. The tendency of zero shift to be reversible suggests this source of error could be minimized by periodic saturation of the hairs during extended periods of continuous low humidities. In dry regions, this might amount to exposing the hairs to a saturated atmosphere for a few hours each month (Middleton and Spilhaus 1953).

Make calibration checks while the relative humidity is leveled off in order to minimize the effects of lag in the response time of the hair element. Do not attempt calibration at low temperatures since the lag of the hair in-

creases greatly at temperatures below 20° F. Base any adjustment of the relative humidity pen on an average of three psychrometer readings obtained with an electric fan psychrometer (see section 11.2).

Adjust the zero if relative humidity indicated on the chart varies more than 3 or 4 percent from average of psychrometer readings. Adjust the pen either up or down by turning the knurled thumbscrew (H) connected to the hair element (G). Briefly lift the pen off the chart during adjustment to eliminate any effects of surface friction between pen and chart.

18.7 RANGE ADJUSTMENT

Temperature Pen

Check the calibration and accuracy of the temperature record for a given period by comparing maximum and minimum temperatures on the chart with those obtained from standard maximum-minimum thermometers. If a consistent difference of more than 2° F. is found after satisfactory zero adjustment, recalibration is indicated. Recalibration for temperature range adjustment is rarely required and unless specific instructions are provided in the instrument manual, return to the manufacturer for this recalibration.

Relative Humidity Pen

When properly adjusted, the humidity pen will register the same as the lowest afternoon humidity obtained by using a psychrometer; the humidity pen will also show a rise of between 95 and 100 percent at night if either fog or dew is present.

Too great or too small a daily spread (range) in a hygrothermograph humidity record is common. Like zero shift, range elongation is a major source of error for relative humidity data collected by hygrothermographs. Range elongation apparently results from exposure to low humidities. Studies at Priest River Experimental Forest in northern Idaho show that range elongation may result from exposure to minimum humidities no lower than 30 percent. These studies also show that the amount of elongation is related not only to the degree of dryness but also to the length of time that low humidities endure (Hayes 1942).

The only remedy for range elongation is to make compensating range shortening adjustments. Conversely, a reduction in the range is corrected by range elongation adjustments. Several methods for making these adjustments follow.

For sake of illustration, assume that the adjustment for low humidity is correct and saturated air is present at night. If the highest humidity on the chart is over 100 percent, the spread must be decreased. If the highest humidity on the chart is below 95 percent, the spread must be increased.

Make the humidity spread adjustment only at the time of day when the humidity pen on the chart has leveled off at its lowest value for an hour or more, preferably on a day when humidity is below 30 percent.

1. *Trial-and-error method.* — (Refer to figures 18.1, 18.2, and 18.3.) This method of adjustment works best for field correction of minor spread errors. It can be performed without interrupting the weather record being collected.

   a. In the afternoons, after relative humidity has leveled off, make an average of three careful psychrometer readings and determine relative humidity (see section 11.3).
   b. Observe the difference between relative humidity determined by psychrometer and the relative humidity indicated by the pen (C) on the hygrothermograph chart.
   c. Mark a pencil line on the magnification bar (I) at the swivel hub (J). This will serve as a reference if you want to start over.
   d. Loosen swivel hub setscrew (J) that holds magnification bar (I) in place (fig. 18.5).
   e. Move magnification bar (I) far enough to change pen setting on chart about one-half the difference in relative humidity observed in step b.

      Move magnification bar (I) out away from chart drum (B) to decrease spread.

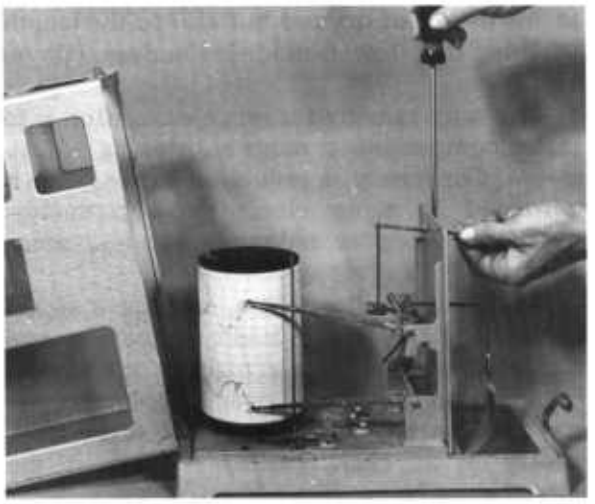


Figure 18.5. — Adjusting the magnification bar on a Belfort hygrothermograph.

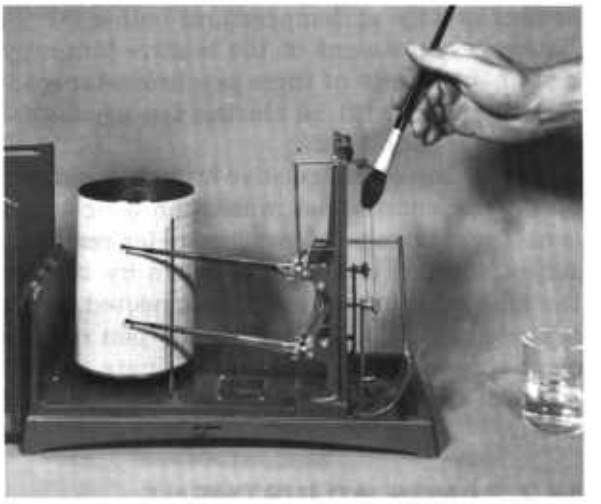


Figure 18.6. — After saturating hair element with a soft camel's hair brush, the humidity pen should indicate between 91 and 95 percent relative humidity.

Move bar (I) in toward chart drum (B) to increase spread.

A movement of 1/8 inch will cause a change in spread of several percent.

f. Tighten the swivel hub setscrew (J) firmly.

g. Since the zero adjustment has now been altered, adjust pen with thumbscrew (H) to correspond with actual psychrometric humidity.

On hygrothermographs of the type shown in figure 18.3, the function of the magnification bar is performed by a hooked magnification lever (S) through which the hair bundle passes. Rotate this lever to the right to increase magnification and to the left to decrease magnification.

On another type of hygrothermograph, the magnification bar (I) is suspended at the right end instead of at its center. It is not adjustable, but a suspension slide that holds the hairs can be moved along the magnification bar. Move the suspension slide out away from the clock to increase the spread. Move the slide in toward the clock to decrease the spread. Note that the movement is opposite from that for the hygrothermographs shown in figures 18.1 and 18.2.

Often, several adjustments over a period of a week or two are required before the proper calibration is obtained by using this trial-and-error method of range adjustment.

2. *Hair-wetting method.* — This is a more precise, time-consuming method. Good results can be obtained in about 2 hours; however, followup with the trial-and-error method is recommended. The wetting method is especially helpful after installing a new set of hairs.

a. Perform this method either outside on a warm, dry afternoon, or inside a warm, dry room.

b. Take three very careful psychrometric readings to determine the correct humidity; set the humidity pen accordingly.

c. Dip a soft camel's hair brush in clean water. Stroke the humidity hairs upward on both sides until they are immersed in a continuous stream of water (fig. 18.6). Hold the water container directly beneath the hairs. Continue this procedure until the hairs are completely saturated. Then stroke all the free water off the hairs, allowing them to spread apart.

d. Immediately after hairs are spread apart, read the humidity on the chart. If the humidity pen is approximately 93 percent, do not change the adjustment.

If the pen indicates over 95 percent, the spread is too great.

If the pen indicates under 91 percent, the spread is too small.

Usually the hairs will indicate approximately 93 percent when saturated with water and 100 percent when saturated with vapor (fog, dew).

e. If adjustment is necessary, follow instructions for moving the magnification bar (I) or hooked magnification lever (S) as outlined in the trial-and-error method.

f. After magnification adjustment has been made, wet the hairs again.

g. Set humidity pen at 93 percent using thumbscrew (H) adjustment.

h. Let instrument sit for at least 30 minutes to permit humidity pen to return to and level off at its former low value. Then set pen according to a new psychrometric humidity reading.

i. Continue to repeat the process until the pen, when wet, will indicate approximately 93 percent, and when dry will indicate the current low humidity as measured by the psychrometer.

Occasionally, a set of hairs will indicate only 80 percent or so when wet with water, but 100 percent when wet with night fog or dew. If this occurs, order and install a new set of hairs. After 3 or 4 days' exposure, proceed with the adjustment process.

3. *Wet-towel method.* — This is the same as the hair-wetting method explained above except the 100 percent point is obtained by surrounding the instrument with wet towels, or by placing it in a box lined with wet towels. If this method is used, the towels should be left until the arm reaches its highest point (approximately 10 minutes) which will be 100 percent relative humidity.

4. *Humidity-chamber method.* — This method (Thornthwaite 1939) involves producing and maintaining a series of different relative humidities within a metal-lined, airtight chamber by means of saturated inorganic salt solutions (table 18.1).

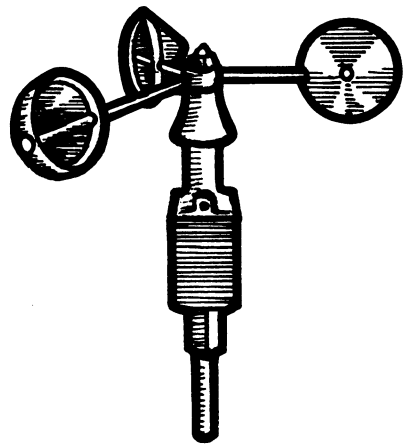
The calibration chamber must be equipped with a fan to insure complete air circulation. The salts should be spread in a shallow pan and distilled water added to produce a thick solution that has an abundance of undissolved material remaining. Refer to Thornthwaite (1939) for additional details regarding this method. The corrosive nature of the salt solutions involved should be considered when using this method of calibration.

CROSS REFERENCE: Description 2.3; Installation and Exposure 8.4; Operation 12.

Table 18.1. — *Relative humidities maintained at specified temperatures by various saturated saline solutions*

Temperature °F.	Relative humidity obtained using saturated solutions of:				
	KNO_3	NaCl	$Mg(NO_3)_2 \cdot 6H_2O$	$MgCl_2 \cdot 6H_2O$	LiCl
	Percent				
104	90	76	51	33	16
95	92	75	51	33	16
86	94	75	52	33	16
77	95	75	52	32	16
68	95	75	53	32	16
59	95	76	53	31	16
50	95	76	53	31	16
41	96	76	54	30	16
32	96	76	54	30	16

CHAPTER 19



ANEMOMETERS

Anemometers are relatively sturdy instruments and can provide many years of trouble-free operation if given reasonable handling and regular maintenance. For most anemometers, maintenance consists of an annual check and monthly or periodic lubrication while in use. During the annual check, the instrument should be disassembled, cleaned, lubricated, and inspected for proper calibration and mechanical soundness.

19.1 CLEANING

All anemometer parts, except the electrical contact unit, may be cleaned with a nonflammable instrument cleaning solvent such as methyl ethyl ketone. Several commercial preparations of this and other acceptable solvents are available under a variety of brand names (MEK, VARSAL, etc.). Do not use preparations containing carbon tetrachloride; it can cause rust, but more importantly, **its fumes are poisonous.** Similarly, do not use gasoline or other highly flammable liquids. Pipe cleaners and small toothbrushes are handy for applying solvent and removing gummed oil or stubborn dirt from anemometer parts.

Electrical contacts should be cleaned first with crocus cloth and then by drawing a clean piece of hard-finish paper between them. Replace the contacts if they are badly pitted or so dirty that a file or emery cloth is needed to clean them. Badly burned or pitted contact points are often the result of too strong an electrical current.

When available, compressed air may be used to good advantage in cleaning out the anemometer housing or removing dirt from around the gears as well as from other hard to reach places.

19.2 LUBRICATION

Depending on the type of anemometer, either anemometer oil or special silicone type lubricants are specified for lubrication. These lubricants are usually available from the anemometer manufacturer. Anemometer oil is simply a light, nongumming instrument oil; thus, any similar light instrument oil can be used. Sewing machine oil and cream separator oil are often recommended as substitutes for anemometer oil. When using substitutes for anemometer oil, use ones that will not impair anemometer operation at low temperatures. Anemometers should be lubricated carefully and sparingly. Wipe off excess oil immediately. Most anemometers require only one or two drops of oil at any one spot. Consider a drop as the amount of oil that will collect at the end of a piece of fine wire (about the size used for paper clips). Such a wire makes a handy applicator. Merely dip the end of the wire into the oil, let the excess run off, and then apply the amount remaining on the end of the wire to the part requiring lubrication.

19.3 MECHANICAL INSPECTION AND RECALIBRATION

Many mechanical deficiencies can be identified by merely spinning the cups and observing their action. You should be able to start the cups spinning by blowing into them. Similarly, the cups should never come to an abrupt stop, even at very low speeds. Hard starting and abrupt stopping may indicate need for oil, need for cleaning, bent or worn parts, or improper assembly. In normal operation, cups should not wobble while spinning. Wobbling often indicates a bent shaft.

Although periodic anemometer calibration checks and necessary recalibrations are critical factors in anemometer peformance, they are often overlooked or purposely avoided. This situation is usually due to the lack of necessary instrumentation or the high cost of having the job done at the factory.

A portable calibrator (fig. 19.1) has recently been developed (Ryan 1970) which allows

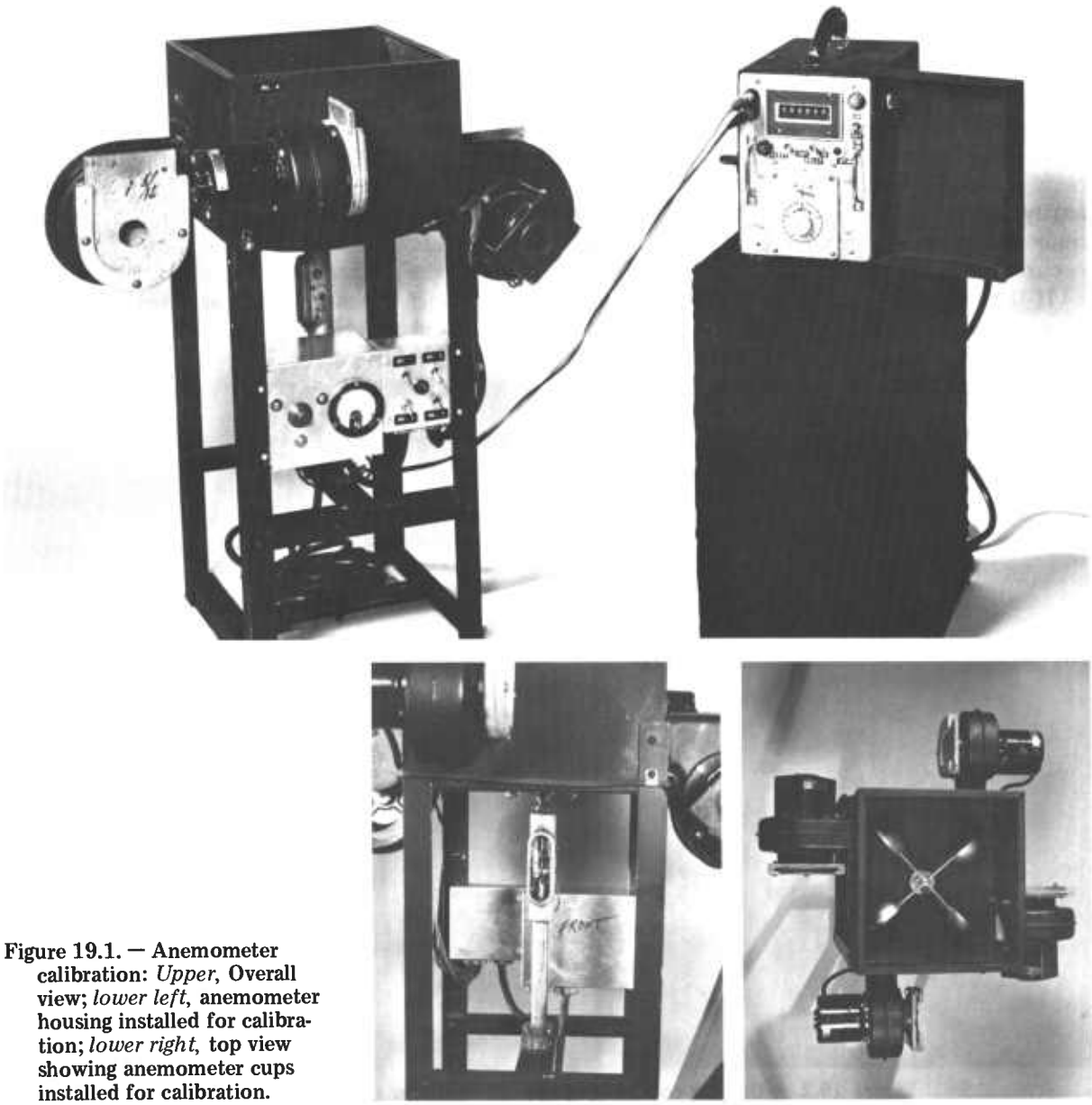


Figure 19.1. — Anemometer calibration: *Upper*, Overall view; *lower left*, anemometer housing installed for calibration; *lower right*, top view showing anemometer cups installed for calibration.

fairly accurate recalibration of anemometers. The unit can be constructed for less than a hundred dollars thereby being within the means of most fire control agency budgets. The recalibration process takes less than 1 hour per anemometer. Ryan reports finding initial calibration errors as high as 28 percent using this instrument.

19.4 CIRCUIT CHECK

A major item when inspecting anemometers for mechanical soundness is to check for a flow of current from the anemometers to the readout device. Check by testing the switch contacts with a continuity tester or attach a wind counter, turn the cups by hand, and record the number of cup revolutions required to advance the counter one count. Now check to see if the anemometer consistently advances the counter one count each time the proper number of cup revolutions occurs.

If the counter or other readout device fails to respond properly, the trouble may be in the wires or connecting cable. Before attempting to check the wiring, however, it is wise to first doublecheck the contact mechanism. If the anemometer is of the multiple contact type the trouble may be that one or more of the pins on the contact wheel are worn short and consequently not closing the contact as they travel past it.

To check for a broken wire in either the anemometer or the readout device, first disconnect the suspected wire. Attach a lead from the continuity tester to one end of the wire and attach the second lead to the other end of the wire to be tested (fig. 19.2). If the arrow on the dial of the continuity tester does not move off the zero position, a break in the wire is indicated.

To check for a short in a multiple conductor cable, first disconnect the cable from the instrument and its readout device. Attach one lead from the continuity tester to the end of one of the wires in the cable. Now touch the other lead from the tester to each of the other wire ends, one at a time. A short is indicated when the arrow on the dial of the tester moves off the zero position. Check each wire in the cable against all the other wires in the same manner.

Detailed maintenance instructions for the

Figure 19.2. — Using a continuity tester to check an anemometer circuit.

types of anemometers likely to be used at fire-weather stations follow. While these instructions are designed to be used cookbook fashion during actual maintenance, we recommend they be first read all the way through before starting disassembly.

19.5 SMALL AIRWAYS TYPE ANEMOMETER

(Friez, Bendix-Friez, and the Instruments Corporation Models)

Refer to figure 19.3.

Monthly Maintenance

Remove front inspection plate (D) and check the spindle (F), top bearings (J), and the worm gear (H). If they need oil, add one to two drops each on the top bearing, the worm gear, and the bottom tip of the spindle. Apply oil carefully and wipe off any excess before replacing inspection plate.

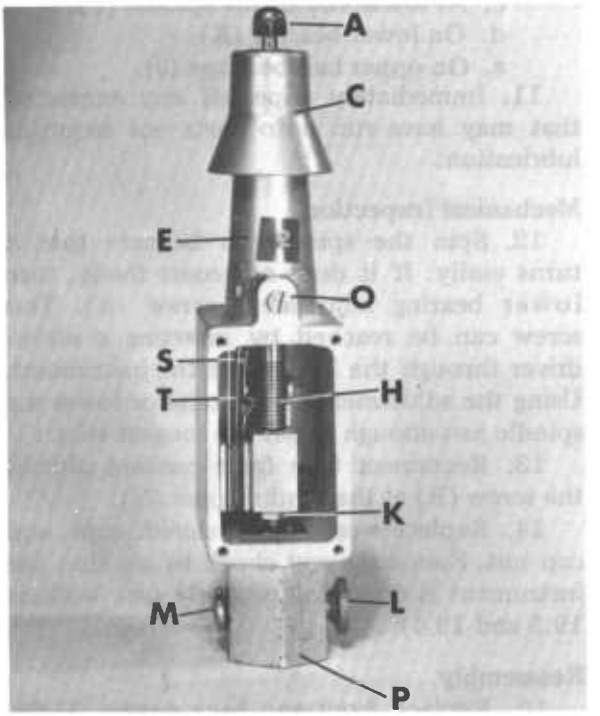
Annual Maintenance

Disassembly

1. Unscrew cap nut (A) and lift off the cups (B) and rain shield (C).
2. Remove front cover plate (D).
3. Loosen set screw (0) above cover plate and lift out the spindle (F).
4. Remove back cover plate (Q) and disconnect wire from contact unit (G) by loosening screw (R) at the binding post (N).

Cleaning and Lubrication

5. Wash spindle, gears, and other parts (but not the contact unit (G)) with instrument cleaning solvent (see section 19.1).
6. Drain and allow to dry.
7. Check contact points (S). If badly pitted, replace. If dirty, clean contact points with crocus cloth and then pull a piece of hard-finish paper between them.
8. Check to make sure positive, but not hard, contact is made when worm wheel pin (I) closes the contact points (S). Bent contact fingers (T) can cause hard contact. To correct this situation, use needle-nose pliers and carefully straighten the contact fingers.
9. Replace spindle and tighten set screw (O).



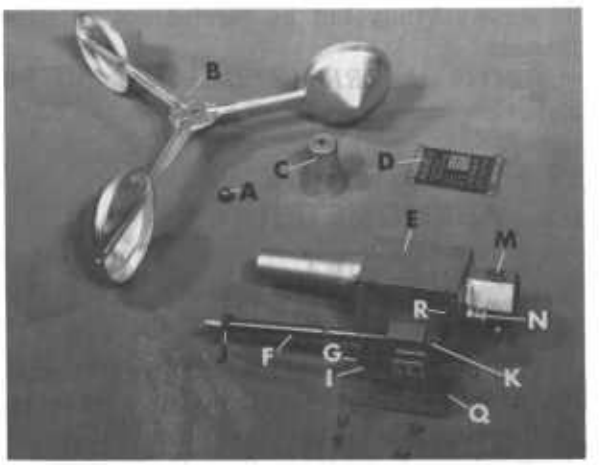


Figure 19.3. — Small Airways type anemometer: *A*, Cap nut; *B*, cups; *C*, rain shield; *D*, front cover plate; *E*, housing; *F*, spindle with worm gear; *G*, contact assembly; *H*, worm gear; *I*, worm wheel; *J*, upper ball bearing; *K*, lower bearing adjustment screw; *L*, thumb clamp screw; *M*, grounded terminal; *N*, insulated terminal; *O*, spindle retaining screw; *P*, mounting sleeve; *Q*, back cover plate; *R*, binding post screw; *S*, contact points; *T*, contact fingers.

10. Apply one drop of anemometer oil (see section 19.2):

a. At each end of the worm wheel shaft (I)
b. At top of gear on the spindle (F).
c. At lower end of the spindle (F).
d. On lower bearing (K).
e. On upper ball bearings (J).

11. Immediately wipe off any excess oil that may have run onto parts not requiring lubrication.

Mechanical Inspection

12. Spin the spindle to be sure that it turns easily. If it does not coast freely, turn lower bearing adjustment screw (K). This screw can be reached by inserting a screwdriver through the bottom of the instrument. Using the adjustment screw, raise or lower the spindle just enough to get the longest spin.

13. Reconnect wire from contact unit to the screw (R) at the binding post (N).

14. Replace washer, rain shield, cups, and cap nut. Spin cups and check to see that the instrument is operating properly (see sections 19.3 and 19.4).

Reassembly

15. Replace front and back covers. Tighten screws firmly but be careful not to strip threads.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5; Operation 13.1.

19.6 FORESTER NO. 9X140 ANEMOMETER

Refer to figure 19.4.

Monthly Maintenance

This instrument requires complete lubrication at least once for every 3 months of uninterrupted use. In order to accomplish this, the instrument has to be taken from the pole, disassembled (items 1-4, below), lubricated (items 8-10, below), and reassembled (items 14-18, below).

Annual Maintenance

Disassembly

1. Unscrew cap nut (A) and remove cups (B).

2. Remove cylinder shell screw (D) on side of cylinder head (C). Use a twisting movement to remove cylinder head and stud (C).

3. Unscrew the slotted screw (H) at top of main shaft (F) which seals the oil channel to the lower bearing. (A few early models have a lockring instead of a screw at this point.)

4. Remove main shaft (F) through bottom of cylinder shell (E). If it sticks, lightly tap the top of the main shaft.

Cleaning and Lubrication

5. Do not attempt to wash the shielded bearings (E). These operate at 0.0001-inch

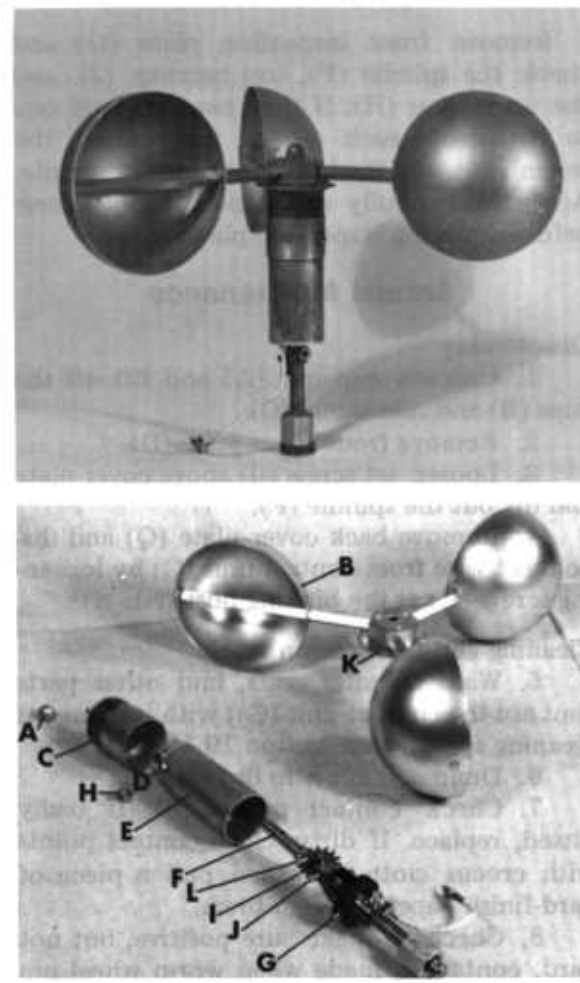


Figure 19.4. — Forester 9X140 anemometer: *A*, Cap nut; *B*, cups; *C*, cylinder head and stud assembly; *D*, cylinder shell screw; *E*, cylinder shell with internal gear; *F*, main shaft; *G*, sprocket gear assembly; *H*, main shaft oil channel screw; *I*, sprocket gear; *J*, contacts; *K*, balance disc; *L*, sprocket gear striking pen.

clearance and cleaning solvents may do more harm than good.

6. Clean all other parts, as needed, using an instrument cleaning solvent (see section 19.1).

7. Check the silver contact points (J) and replace if badly burned or pitted. If dirty, clean with crocus cloth and then by pulling a piece of hard-finish paper between them.

8. Place two drops of anemometer oil on the shield of each bearing (see section 19.2).

9. Place one drop of anemometer oil on sprocket gear shaft (I).

10. Place two drops of oil at top of internal gear located inside the cylinder shell (E).

11. Immediately wipe off any excess oil that may have run onto parts not requiring lubrication.

12. Check the contact mechanism (J) by rotating the sprocket gear (I) and observe whether the striking pin (L) causes the bronze fingers (J) to make and break contact. The movement of the inside contact point should be between 1/32 and 1/16 of an inch. The outer contact point should deflect about 1/64 of an inch.

13. Check to see that the screws holding the contact arms are tight and secure.

Reassembly

14. Insert main shaft (F) into bottom of cylinder shell (E) and up through the two bearings.

15. Install the oil channel screw (H) (or lockring) at top of shaft.

16. Using a twisting motion, push on the cylinder head (C), line up the hole in the side, and tighten the screw (D).

17. Replace the balance disc (K) being careful to keep the side marked "top" on top.

18. Replace cups and tighten the cap nut.

19. Spin cups and check instrument for proper operation (sections 19.3 and 19.4).

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5; Operation 13.1.

19.7 FORESTER MODEL 9X150

Refer to figure 19.5.

Monthly Maintenance

This instrument does not require monthly maintenance if proper annual maintenance is provided.

Annual Maintenance

Disassembly

1. Remove 1/8-inch pipe plug from side of the body and drain the versilube fluid from the instrument. NOTE: Versilube is a special synthetic lubricant which will neither congeal nor impair operation at subzero temperatures. A bottle of this fluid is supplied with each instrument and additional quantities can be ordered from the manufacturer. DO NOT USE ANY OTHER LUBRICANT.

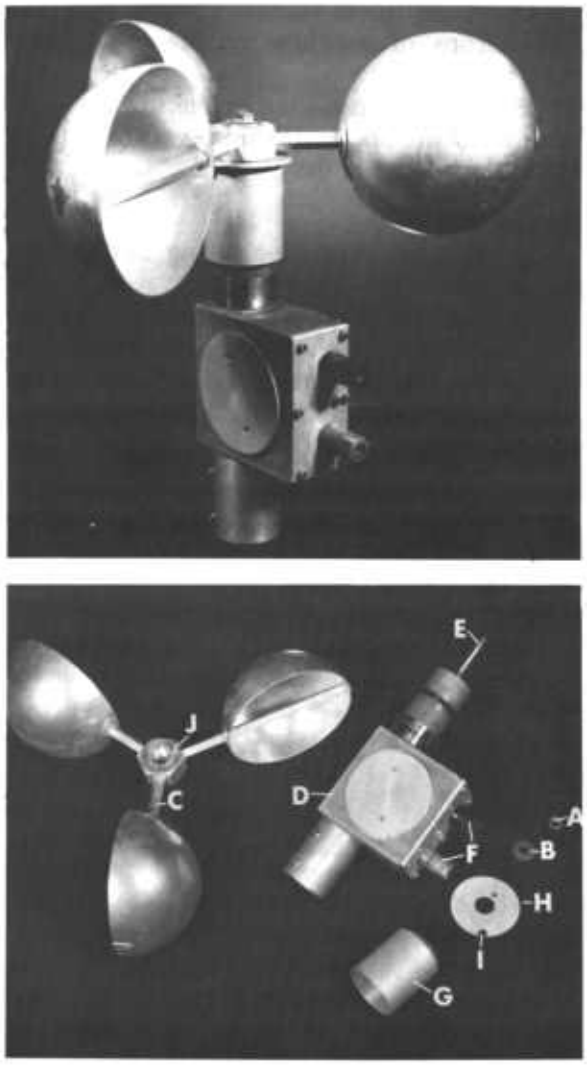


Figure 19.5. — Forester Model 9X150 anemometer (upper) assembled view, (lower) unassembled view: *A*, Cap nut; *B*, washer; *C*, cups; *D*, housing; *E*, upper main shaft; *F*, exterior terminal posts; *G*, rotor cap; *H*, balance disc; *I*, balance weight; *J*, rotor hub pin.

2. Unscrew 1/4-inch stainless steel cap nut (A) and washer (B) on top of cups. Remove cups (C), balance disc (H), and rain shield (G). Do not disturb the small weight (I) on the balance disc.

Cleaning and Lubrication

3. Clean dust and oil residue from exterior of housing (D), cups, interior of the rain shield, and the brass surfaces of the terminal posts (F).

4. Briefly turn anemometer upside down. The versilube fluid remaining in the body will lightly lubricate lower main shaft bearing.

5. Turn anemometer upright and add three drops of versilube on the upper main shaft bearing.

6. With anemometer in the upright position, refill the body with fresh versilube fluid. Fill to lower edge of the fill hold.

Reassembly

7. Replace pipe plug, using Teflon pipe thread tape.

8. Replace the rain shield and the balance disc. Replace the cups making sure that the pin (J) on the hub is seated in the holes on the balance disc and rain shield. Replace the washer and the cap nut.

Mechanical Inspection

9. Spin shaft and check for any binding action. If binding occurs, check for improper assembly, bent or worn parts, dirt, and need for oil.

10. Use a continuity tester and check switch contacts. Every 15 turns of the cups should make one contact (see section 19.4).

11. If the anemometer does not appear to operate properly, return it to the manufacturer. Do not disassemble any further than indicated above as the mercury switch inside the housing is easily broken.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5; Operation 13.1.

19.8 CHISHOLM MODEL 2B3C ANEMOMETER

Refer to figure 19.6.

Monthly Maintenance

Remove cap nut, screw, or bolt from top of cups. Place one to three drops of oil in the oil duct which is exposed when the cap nut, screw, or bolt is removed.

Annual Maintenance

Disassembly

1. Unscrew cap nut (A) and lift off the cups (B).

2. Remove mounting nut lockring (N) and slide mounting nut (O) from main shaft (D).

3. Remove the small bolt that goes

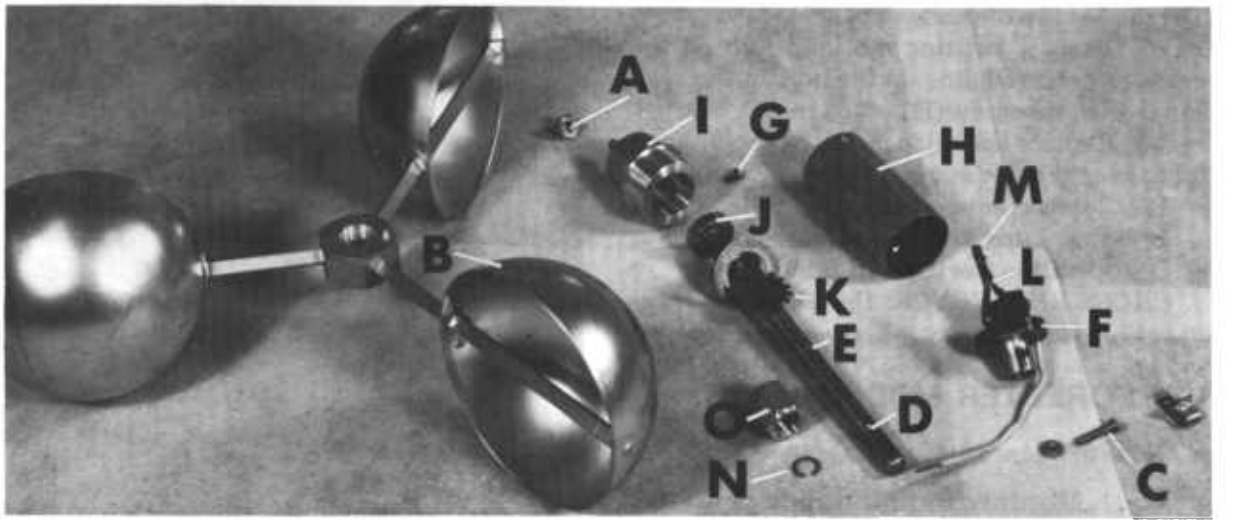


Figure 19.6. — Chisholm Model 2B3C anemometer: *A*, Cap nut; *B*, cups; *C*, electrical unit retaining bolt; *D*, main shaft; *E*, electrical unit mounting point; *F*, electrical unit; *G*, cylinder retaining screw; *H*, revolving cylinder; *I*, cylinder head; *J*, roller bearings; *K*, sprocket gear; *L*, contact fingers; *M*, contact points; *N*, mounting nut lockring; *O*, mounting nut.

through the main shaft (D) at point (E).

4. Carefully slide the electrical contact unit (F) down over the end of the main shaft (D).

5. Remove the small screw (G) from the revolving cylinder (H). Hold the revolving cylinder with one hand and remove the cylinder head (I) by turning it to the left with the other hand.

6. Remove the main shaft (D) from the cylinder head (I).

Cleaning and Lubrication

7. **Do not** attempt to wash the electrical contact unit (F).

8. Wash all other parts in an instrument cleaning solvent (see section 19.1).

9. Put two drops of anemometer oil around the top of the two roller bearings (J) of the main shaft (see section 19.2).

10. Put two drops of anemometer oil around the worm gear located inside the top of the revolving cylinder (H).

11. Immediately wipe off any excess oil that may have run onto parts not requiring lubrication.

Mechanical Inspection

12. Check the contact mechanism by slipping the entire electrical contact unit on the shaft and temporarily fastening it into place. Manually turn the sprocket gear (K) and see if the striking pin causes the bronze fingers (L) to make and break contact at the silver contacts (M). Remove the contact unit from the shaft.

Reassembly

13. Place cylinder head (I) on top of the roller bearings (J). Put the revolving cylinder (H) up over the shaft (D) and on the cylinder head (I). Turn it to the right to match up the holes. Replace the small screw (G).

14. Turn anemometer upside down and rotate the revolving cylinder until the small pin on the gear wheel (K) is face up and in line with the shaft. **Carefully** slide the electrical contact unit up over the shaft and into the revolving cylinder. At this point, the contact points should be to the **left of the main shaft** when the anemometer is pointing away from you.

15. Replace the small bolt (C) through the electrical unit and shaft.

16. Replace cups and tighten cap nut.

17. Spin cups and check to see that the anemometer is operating properly (see sections 19.3 and 19.4).

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5; Operation 13.1.

19.9 STEWART ALUMINUM CUP ANEMOMETER

Refer to figure 19.7.

Monthly Maintenance

According to manufacturer's instructions, this instrument does not require monthly service unless electrical contact points need adjustment (see item 8, below).

Annual Maintenance

Disassembly

1. Loosen set screw on side of the hub and lift off cups.

2. Loosen screws and remove cover plate from the housing (A).

3. **Do not** remove the nylon pinion gear (F) or loosen the brass bearing blocks (C) at the ends of the shaft. If you do, tiny ball bearings will fall out. These are extremely difficult to replace.

Cleaning and Lubrication

4. Using a clean, soft cloth, wipe off the top of the spindle (B), the spindle sleeve, and the inside of the hub. Lightly oil each of these areas with silicone fluid lubricant.

5. Place several drops of silicone fluid on the spindle just above the top bearing and just above the lower bearing. Now spin the spindle clockwise to work the lubricant into the bearings.

6. Put a small amount of silicone grease (or vaseline) on the gear pinion (F) where the ground strap is attached.

Mechanical Inspection

7. Spin shaft and check for friction or binding. If it binds, check for improper assembly, bent or worn parts, dirt, and need for oil.

8. Check the action of the contact leaf spring (D). If necessary, adjust the spring contact so it is just barely moved by the pin on the ring gear. If too tight, excessive wear will result

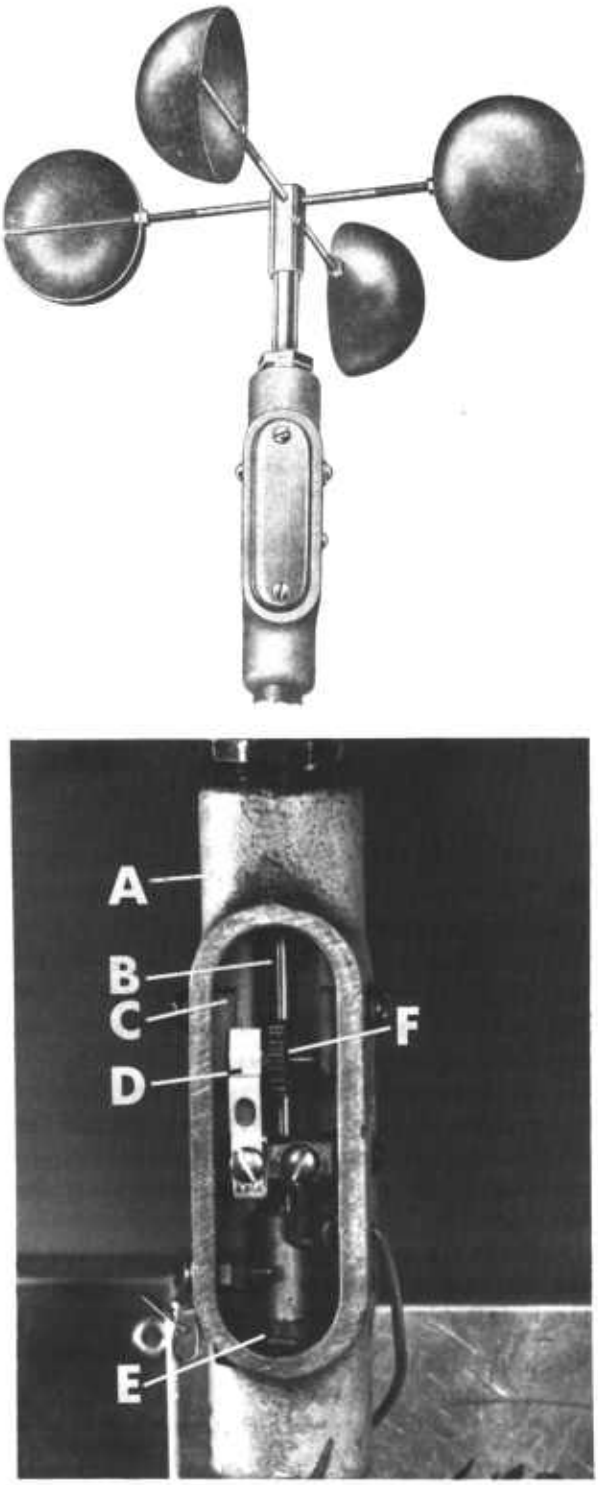


Figure 19.7. — Stewart aluminum cup anemometer: *A*, Housing; *B*, spindle; *C*, bearing block; *D*, contact leaf spring; *E*, lower thrust bearing; *F*, pinion gear.

and the anemometer will stick at low windspeeds; if too loose, the attached readout device may not indicate properly.

Reassembly

9. Replace cups and tighten setscrew.
10. Replace cover plate.
11. Spin cups and check to see that the anemometer is operating properly (see sections 19.3 and 19.4).

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5; Operation 13.1.

19.10 STEWART 4-CUP ANEMOMETER

(Models prior to 1959; with black cups)

Refer to figure 19.8.

Monthly Maintenance

Remove the inspection plate (A) and check the top and the bottom of the spindle (C). If dry, add one to two drops of oil at each of these locations. Some models contain an oil duct on top of the rotor for lubrication of the top of the spindle. This duct often becomes plugged up and may require cleaning. If duct is lacking, remove cups and apply oil to the top of the spindle. Apply oil carefully and wipe off any excess before replacing the inspection plate.

Annual Maintenance

Disassembly

1. Remove screw on the top of cup assembly hub and remove cups. If there is no screw on top, loosen set screw in the side of hub and slip cups off the hub. If cups will not slip off after removing setscrew, hold the anemometer shaft with one hand and use the other hand to unscrew cups.
2. Remove the cover plate (A).
3. Always keep the housing (B) in an upright position. If turned upside down, four small ball bearings will fall out.
4. Unscrew bushing shaft from housing and slide over spindle (C). Remove spindle carefully. If it offers resistance, move it from side to side until it lifts out.
5. Do not remove pinion gear (E) or loosen the brass bearing block at end of shaft. If you do, the tiny ball bearings contained with-

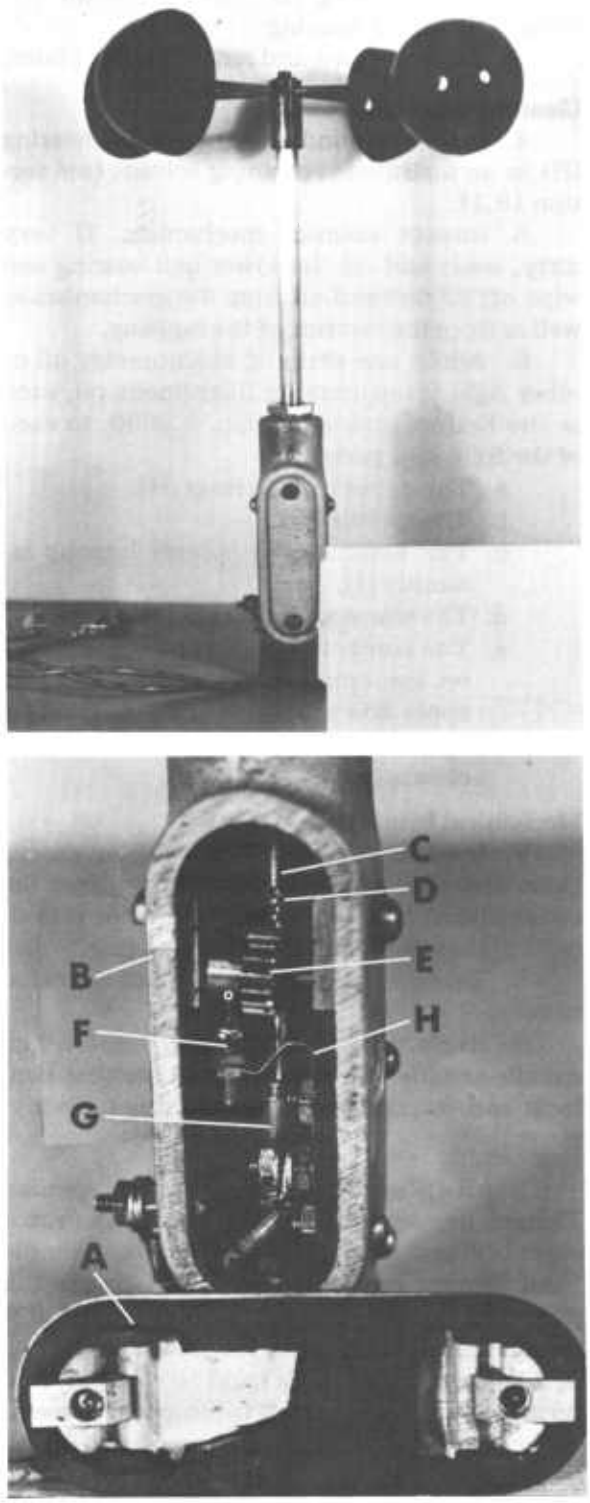


Figure 19.8. — Stewart 4-cup anemometer: *A*, Cover plate; *B*, housing; *C*, shaft; *D*, worm gear; *E*, pinion gear; *F*, contact points; *G*, lower thrust bearing; *H*, contact leaf spring.

in might fall out. They are extremely difficult to replace.

Cleaning and Lubrication

6. Wash the gears, shaft, spindle, and other parts in instrument cleaning solvent (see section 19.1). Flush the entire housing with solvent.

7. Insert the spindle temporarily and work it around and up and down.

8. Drain solvent from housing and set aside until dry.

9. Put two drops of anemometer oil on the gears (see section 19.2).

10. Put two drops of anemometer oil at the top of the shaft (through the hole in the top of the hub, if present) to lubricate the upper bushing.

11. Immediately wipe off any excess oil.

Mechanical Inspection

12. Replace gears, spindle, and shaft. Replace cups and tighten setscrew. Spin cups slowly and check for friction or binding (see sections 19.3 and 19.4).

13. Check the action of the contact leaf spring (H). If necessary, adjust the spring contact so that it is just barely moved by the pin on the pinion gear (E). If too tight, excessive wear will result and the anemometer will stick at low airspeeds; if too loose, the attached readout device may not indicate properly.

14. If unable to correct mechanical difficulties by cleaning, oiling, or adjustment, the instrument should be replaced by a newer model anemometer.

Reassembly

15. Replace the gasket. If the gasket is similar to the one in figure 19.8, put the cutout portion up so the pinion gear (E) will not bind on it.

16. Replace cover plate.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5; Operation 13.1.

19.11 BELFORT TOTALIZING ANEMOMETER

Refer to figure 19.9

Monthly Maintenance

Maintenance should be performed at least every 3 months, more often if anemometer is

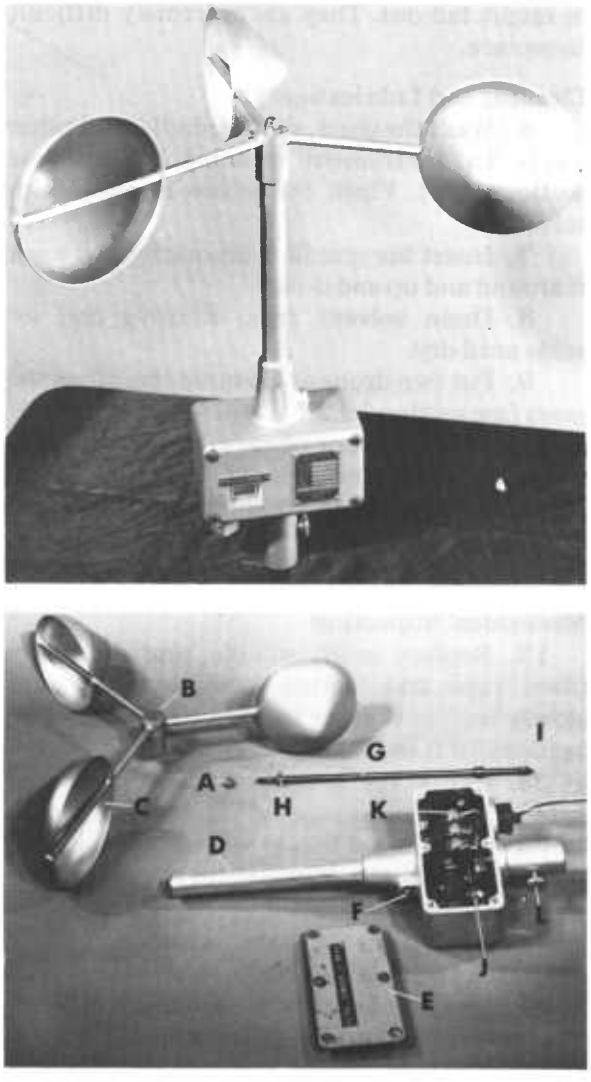


Figure 19.9. — Belfort totalizing anemometer: *A*, Cap nut; *B*, hub screw; *C*, cups; *D*, housing; *E*, back cover plate; *F*, spindle retaining screw; *G*, spindle; *H*, upper ball bearings; *I*, worm gear; *J*, worm wheel with pins; *K*, terminal block assembly; *L*, thumbscrew.

constantly exposed to excessive dust, frequent rains, or strong continuous windspeeds. This periodic maintenance should be the same as outlined below for annual maintenance.

Annual Maintenance

Disassembly

1. Remove the cap nut (A), loosen setscrew (B) in the hub of cup assembly, and remove the cups (C).

2. Release spindle retainer screw (F) located in the housing (D) and lift spindle (G) straight up out of housing.

3. Remove front and rear (E) cover plates.

Cleaning and Lubrication

4. Wash the spindle and upper ball bearing (H) in an instrument cleaning solvent (see section 19.1).

5. Inspect counter mechanism. If very dirty, wash and oil the lower ball bearing and wipe off all dirt and oil from the mechanism as well as from the interior of the housing.

6. Apply one drop of anemometer oil or other light, nongumming instrument oil, such as the Belfort Instrument Co. # 5600, to each of the following points:

a. The upper ball bearings (H).
b. The spindle (G).
c. The worm, lower spindle bearing assembly (I).
d. The worm assembly (J).
e. The contact operating pins — but not on the contacts themselves. Do not apply too much oil — use only a few drops for the entire lubrication procedure (see section 19.2).

Mechanical Inspection

7. Inspect contacts. Clean with crocus cloth and pull a piece of hard-finish paper between them. If contacts are burned or pitted, replace them and check for overloading.

8. Replace counter and contact mechanism.

9. Replace the spindle and tighten the spindle retainer screw. Check to see that contacts and worm wheel are operating properly.

Reassembly

10. Replace the cups on the spindle. Tighten the setscrew in the hub of the rotor assembly just enough to prevent the spindle from turning while the cap nut is being put in place and tightened snugly. After the cap nut is installed, finish tightening the setscrew.

11. Spin the cups by hand to see that they turn freely. If not, check for improper assembly, bent or worn parts, dirt, and need for oil (see sections 19.3 and 19.4).

12. Replace and cover plates.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5; Operation 13.1, 13.2.

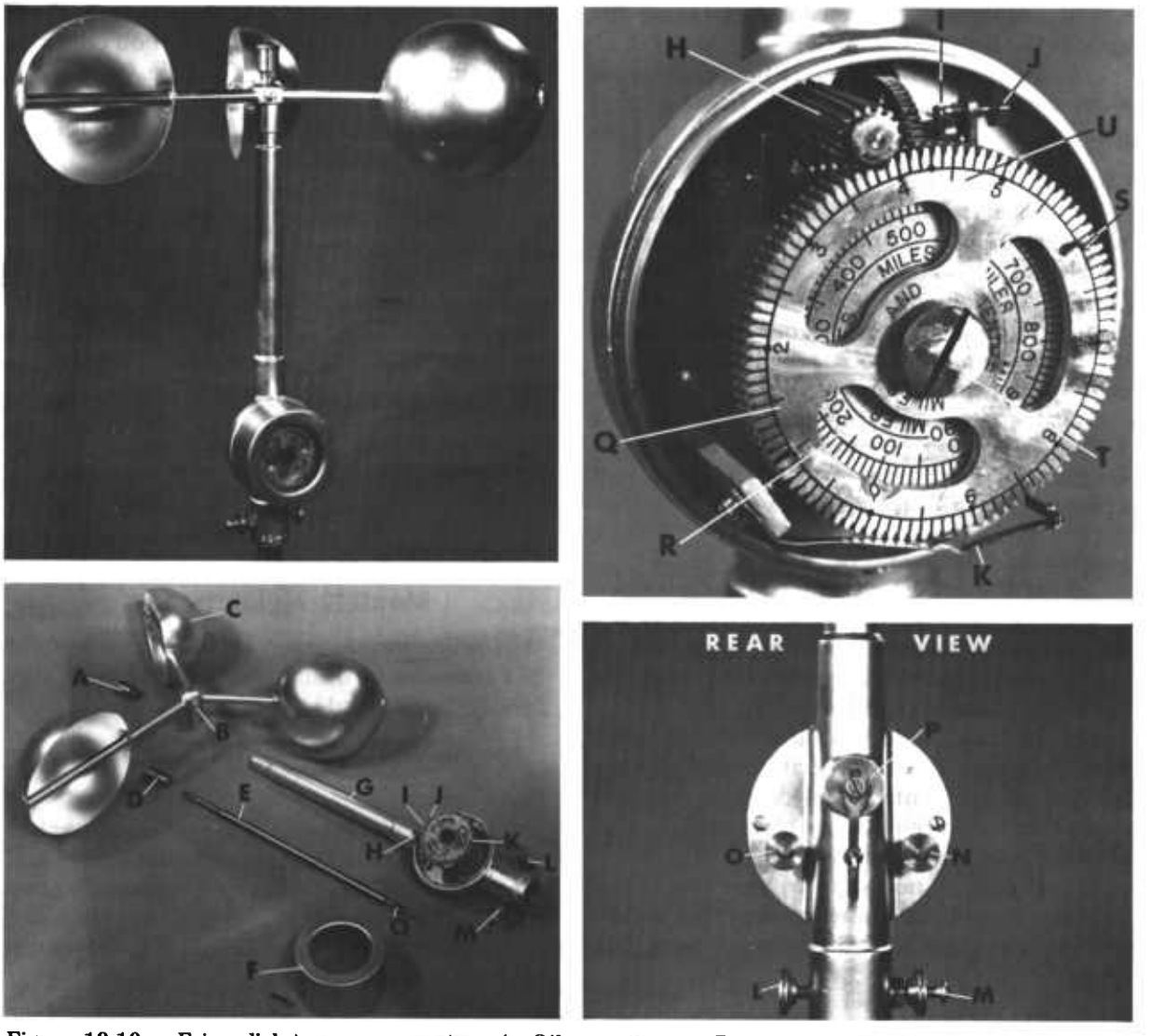


Figure 19.10. — **Friez dial type anemometer: *A*, Oil cup-cap nut; *B*, rotor hub set screw; *C*, cups; *D*, top bushing; *E*, spindle with worm; *F*, dial cover plate; *G*, housing; *H*, gears; *I*, 1/60-mile contact; *J*, contact adjustment screw; *K*, 1-mile contact; *L*, thumbscrew clamp; *M*, grounded terminal; *N*, 1/60-mile terminal; *O*, 1-mile terminal; *P*, oil point plug; *Q*, outer dial wheel; *R*, inner dial wheel; *S*, 1-mile contact pin; *T*, dial screw; *U*, location of 10-mile bar.**

19.12 FRIEZ DIAL TYPE ANEMOMETER

Refer to figure 19.10.

Monthly Maintenance

Remove plug (P) from backside of housing (G) (side opposite dial). Put one drop of oil at the top of the worm gear (Q) on the spindle (E). Put one drop of oil at the lower end of the spindle where it enters the lower bearing.

Unscrew top from oil cup (A) at top of anemometer. Check to see that wicking extends down the center pipe. Fill cup about half full of oil.

Annual Maintenance

Disassembly

1. Unscrew brass oil cup and cap nut (A).
2. Loosen setscrew (B) and remove cups (C).

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3. Unscrew top bushing (D) and lift spindle (E) from housing (G).

4. Remove cover plate (F) on dials by removing the two holding screws. Leave dials in place.

Cleaning

5. Clean spindle (E) and top bushing (D) with instrument cleaning solvent (see section 19.1).

6. Blow out oil duct in top of spindle to clear it of all obstructions from the top to the small hole in the side of the spindle at the level of the top bushing.

7. Inspect contact points. If either the 1/60-mile contact (I) or the mile contact (K) are dirty, clean with crocus cloth and then pull a piece of hard-finish paper between them.

Mechanical Inspection

8. If the 1/60-mile contacts do not open sufficiently, increase the clearance by turning the contact adjustment screw (J) to the left. If the contact closure is insufficient, turn the contact adjustment screw to the right.

9. If the 1-mile contacts do not open enough, loosen the screw that holds the lower portion of the contact and drop the contact down slightly. If they do not close sufficiently, lift the contact up slightly.

10. It may be necessary to bend the spring section of each of these contacts to secure proper operation but this should be a last resort.

Reassembly

11. Return the spindle, making sure it is seated in the bottom bearing. Replace top bushing.

12. Replace cups and tighten setscrew.

Lubrication

13. Put one drop of anemometer oil on each gear wheel on the front of the dial. Replace glass dial cover and tighten holding screws (see section 19.2).

14. Remove plug (P) from housing on back of dial. Put one drop of anemometer oil at the top of the worm gear on the spindle. Put one drop of oil at the lower end of the spindle where it enters the lower bearing. Replace plug.

15. Unscrew cover from brass oil cup. If wick is absent, one can be made from heavy cotton sewing thread. It should lead from the oil cup down to the oil duct. Fill oil cup with anemometer oil to level of spindle.

16. Replace oil cup on top of spindle and check hole in spindle to be sure that oil is flowing onto the bushing.

17. Spin cups by hand and check to see that anemometer is operating properly (see sections 19.3 and 19.4).

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5; Operation 13.1, 13.2.

19.13 WEATHER MEASURE W164 AND W164B CONTACT ANEMOMETER

Refer to figure 19.11.

Monthly Maintenance

Routine monthly service is not required for this instrument if annual maintenance is performed as specified below.

Annual Maintenance

Disassembly

1. If Model W164B, remove its mechanical counter by removing the counter face plate and the fastener in the back of the counter. To free the counter from the housing, simply press the entire assembly forward. Model W164 does not have a mechanical counter.

2. Remove the cups (A) by unscrewing the lock nut (B) and cap nut (C) at the top of the shaft (H) and pushing upward gently at the base of the shaft.

3. Remove the bearing setscrew (D) on the side of the housing (I). Now remove the bearing oil seal (E) at the top of the shaft (H) by turning upward and off the base assembly. Remove the top bearing (F).

4. Loosen the top housing lock pin (K) and turn the top assembly upward and off the bottom housing (L).

5. To disassemble further, remove the bottom gear plate from the bottom support assembly by lifting it upward and off the guide pin.

6. Care must be taken to maintain the proper shaft bearing clearance during assembly. To assure the correct clearance, scribe indica-

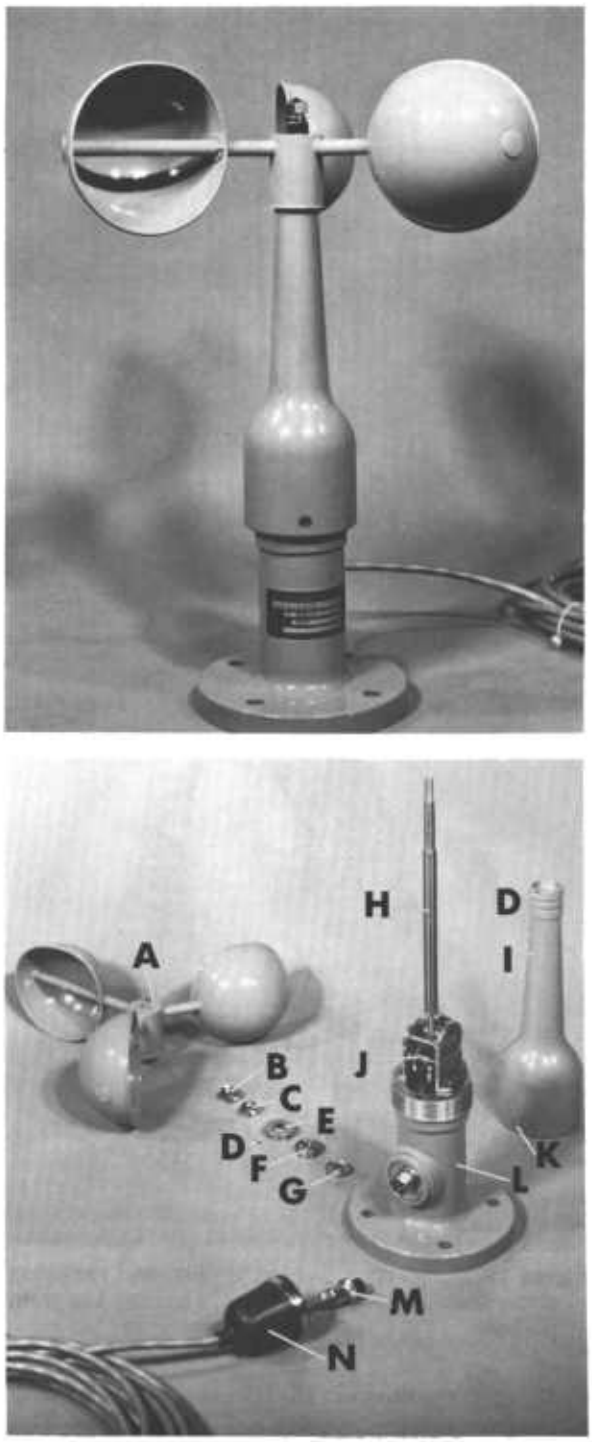


Figure 19.11. — Weather Measure W164 contact anemometer: *A*, Cups; *B*, cap lock nut; *C*, cap nut; *D*, top lock screw; *E*, bearing oil seal; *F*, top bearing; *G*, bearing oil seal; *H*, drive shaft with worms; *I*, top housing; *J*, drive gear; *K*, top housing lock pin; *L*, bottom housing; *M*, cannon plug; *N*, weather boat.

ting marks on the bottom bearing support and base-plate assembly prior to disassembly.

7. To remove the shaft (H), loosen the bottom bearing by screwing it down until sufficient clearance is accomplished to slip the shaft off the worm and out of the bottom assembly.

Cleaning and Lubrication

8. Lubricate the bottom and the top bearing with anemometer oil that preferably has a silicone base. Use a dry film lubrication on the gears (see section 19.2).

Mechanical Inspection

9. Check the contacts. Replace them if they are pitted or burned and check for overload or inadequate spark suppression.

Reassembly

10. Replace shaft, being careful to maintain the proper shaft bearing clearance.

11. Return the bottom gear plate to the bottom support assembly.

12. Screw the top assembly on to the bottom housing. Tighten the top housing set screw.

13. Replace the top bearing and the bearing oil seal. Tighten bearing setscrew.

14. Replace cups and screw down the cap nut and then the cap lock nut.

15. Spin cups and test operation (see sections 19.3 and 19.4).

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.5; Operation 13.1.

19.14 DWYER WIND METER

Refer to figure 19.12.

Maintenance requirements for this instrument are relatively simple. It must be kept clean, dry, and static free.

Cleaning

1. Clean the outer shell (A) with a damp cloth. Do not use cleaning agents that attack plastic.

2. Clean inner tube (B) by using either the treated pipe cleaners provided with the instrument or regular pipe cleaners (fig. 19.13). Before cleaning inner tube, unscrew the metal plug (D) on the bottom and remove the white

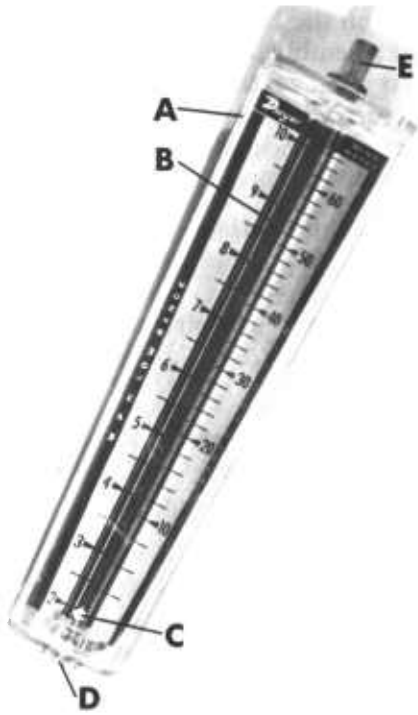


Figure 19.12. — Dwyer hand-held wind meter: *A*, Outer shell; *B*, inner tube; *C*, indicator ball; *D*, bottom plug; *E*, top stem.

ball (C). After cleaning, replace ball and metal plug.

Do not press on the white indicator ball with fingers or other objects as it is easily deformed and damaged, rendering it unusable or unreliable.

Drying

If moisture enters the inner tube, unscrew bottom plug and remove white ball. Clean tube with a pipe cleaner (fig. 19.13). After all moisture has been removed, replace ball and return metal plug.

Removing Static

A static electricity charge may cause the ball to stick in the tube. This can be corrected by running a pipe cleaner up and down in the tube (fig. 19.13). Follow procedure as in cleaning or drying the tube.

Calibration

Proper calibration depends on the instrument being maintained in a clean, dry, and

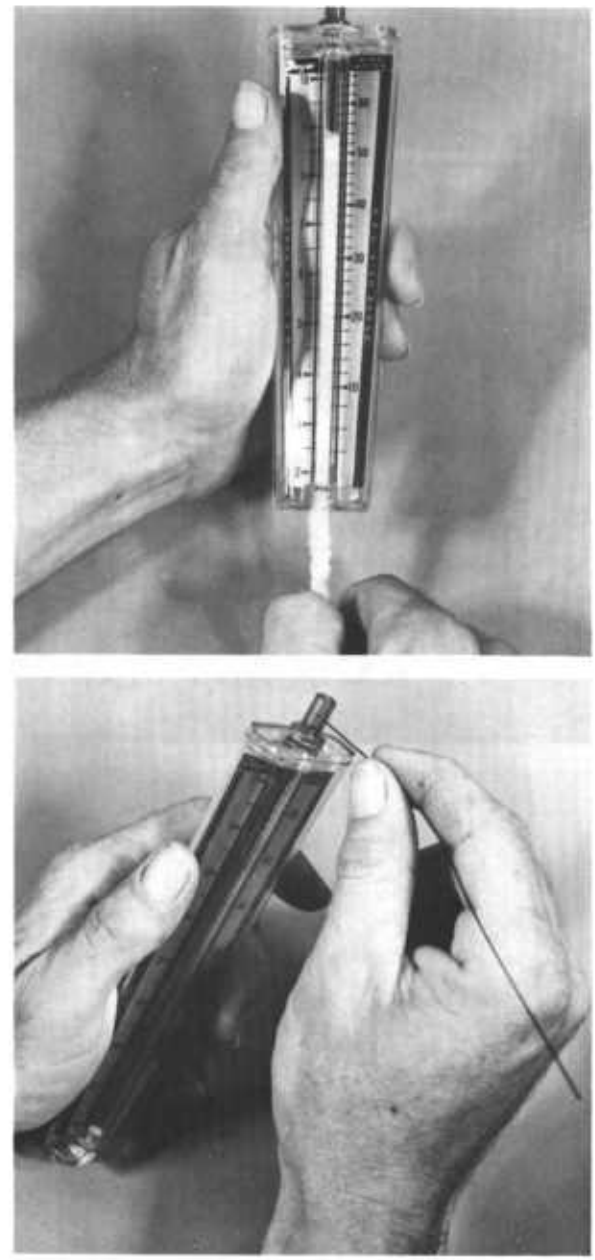
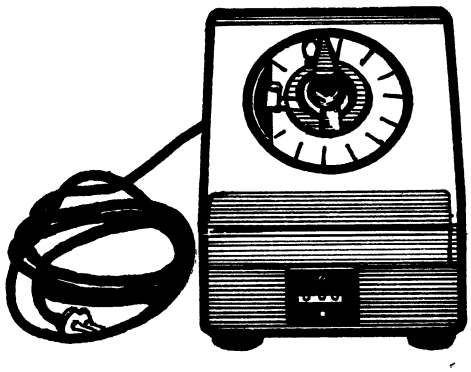


Figure 19.13. — *Top*, Cleaning, drying, and removing static from inner tube; *bottom*, cleaning top stem pinhole.

static-free condition. Be sure to keep the tiny pinhole in the top stem (E) clean and open. Use nylon bristles provided with the meter to accomplish this task (fig. 19.13). Do not use wire, pins, drills, etc., which might accidentally enlarge the opening.

CROSS REFERENCE: Description 3.1; Operation 13.4.

CHAPTER 20



WIND COUNTERS

Maintenance requirements for wind counters are mainly concerned with the electrical circuit. Items such as maintaining sufficient battery strength; clean, tight electrical connections; and sound wiring are critical to continuous trouble-free operation.

20.1 BUZZERS AND FLASHERS

1. Install fresh batteries whenever the buzz or flash becomes weak.
2. At least once a year, clean buzzer contacts with crocus cloth and hard-finish paper.
3. Periodically check electrical connections for tightness. Remove corrosion as it accumulates.
4. If buzzer fails to operate, or operates weakly or intermittently, follow this procedure successively until the trouble is corrected:
   a. Replace batteries. Make sure that they are hooked in series rather than parallel (fig. 20.1).
   b. Replace lamp or flasher.
   c. Check the buzzer contacts. Burned contacts indicate too much current. Usually two to four 1½-volt dry cells are enough; the number depends on the line distance, buzzer voltage, and battery strength.
   d. Check all electrical connections on buzzer. Snap off the cover and check the inside connections.
   e. Using a rubber handle screwdriver, short across from switch to buzzer. If there is no response, clean the buzzer contacts. If contacts are clean and trouble persists, bend the vibrator closer to the magnet. If this does not correct the malfunction, replace the buzzer.
   f. Short across the terminals successively at the lightning arrester on the buzzer or flasher side, then on the anemometer side, and last, create a short at the anemometer itself by touching the lead wires together.
   g. If buzzer sounds or lamp lights each time the above shorts are made, the trouble is in either the anemometer lead wires or the anemometer itself.
5. If buzzer or flasher operates continuously when the switch is closed, check all circuits for shorts or bare wires.

CROSS REFERENCE: Description 3.1; Operation 13.1.

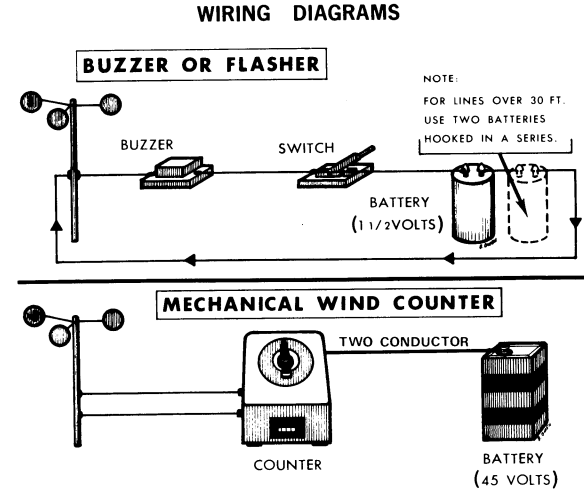


Figure 20.1. — Wiring diagrams: *Upper*, Buzzer or flasher; *lower*, mechanical wind counter.

Maintenance instructions for the more commonly used mechanical wind counters follow.

20.2 FORESTER 9X156 WIND COUNTER, MODEL 1

Refer to figure 20.2.

Annual Maintenance

1. Clean the exterior of the counter. Use nonflammable instrument cleaning solvent to remove stubborn dirt.
2. Carefully open counter and clean the inside using a soft brush. Use instrument cleaning solvent to remove stubborn dirt.
3. Check all electrical connections inside the counter. Tighten loose connections and resolder broken connections. Use rosin-core solder.
4. Reassemble counter and check the timer for accuracy. If necessary, adjust timer setting as follows:
    a. Loosen locking lug.
    b. Rotate timer stop to correct position.
    c. Tighten locking lug.
5. Inspect battery leads and install a fresh battery. Remove any dirt or corrosion from battery leads and replace any worn or broken lead wires.
6. Inspect anemometer leads and clean and replace as necessary.
7. Test wind counter by attaching a contacting anemometer (fig. 20.1). Spin the cups by hand and observe if the counter advances each time the anemometer closes a contact. The counter can also be tested by touching the counter leads together at 1- to 1½-second intervals.

Periodic Maintenance and Troubleshooting

1. Occasionally check the timer against a stopwatch. Reset if necessary.
2. In the event of counter failure, proceed as follows:
    a. Replace battery and check battery lead wires for visible signs of wear or breaks.
    b. Remove one anemometer lead wire from the counter.

Figure 20.2. — Forester 9X156 Wind Counter, Model 1.

    c. Set timer and while it is running, use a short piece of wire and short across from one binding post to the other, alternately making and breaking the circuit.
    d. If counter advances each time the circuit is closed, the trouble is in the anemometer or the anemometer lead wires. Check the lead wires with a continuity tester (see section 19.4) and replace if necessary. If lead wires are sound, refer to maintenance instructions for anemometer and check contacts and electrical connections accordingly.
    e. If counter fails to advance when circuit is closed, and all the previous steps have been followed, test battery lead wires for continuity (see section 19.4). If trouble is not found here, the counter should be checked by an electronic technician.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.6; Operation 13.1.

20.3 HAYTRONICS TOTALIZING WIND COUNTER

Refer to figure 20.3.

This instrument has the same maintenance requirements as the preceding Forester 9X156.

Figure 20.3. — Haytronics totalizing wind counter.

The main difference between them is that the Haytronics has an "off-on" switch rather than a timer dial. With this in mind, follow the maintenance instructions for the Forester 9X156 wind counter.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.6; Operation 13.1.

20.4 STEWART ELECTRONIC ODOMETER

Refer to figure 20.4.

Annual Maintenance

1. Clean exterior of counter. Use instrument cleaning solvent to remove stubborn dirt.
2. Open counter by lightly squeezing on the sides and slowly pulling the two sections straight apart. Flexible wires on the two switches will allow the sections to be separated sufficiently to reach the interior.
3. Clean interior of counter with instrument cleaning solvent and a soft brush.
4. Check all connections inside the counter. Tighten loose connections and resolder broken connections. Use rosin-core solder.
5. Carefully close the counter box, making sure not to pinch any of the interior wiring between the two sections or to disturb the transistors in their sockets. Loop the switch wires into accordion folds and then squeeze the sides of the box and slide the front cover (A) slowly and squarely onto the back section.
6. Inspect battery lead wires (Fand G) for wear, breaks, or corrosion. Clean, repair, or replace as necessary. Install a fresh, heavy-duty, 6-volt lantern battery that has screw posts.
7. Inspect anemometer lead wires for wear, breaks, or corrosion. Clean, repair, or replace these wires as necessary.
8. Push up on the right-hand switch of the counter front. This is the "on" position and should cause the right-hand counter wheel to advance one count. This is a self test of the instrument.

If the counter does not advance one count when the power switch is turned "on," do any of the following until the trouble is corrected:

a. Check battery polarity.

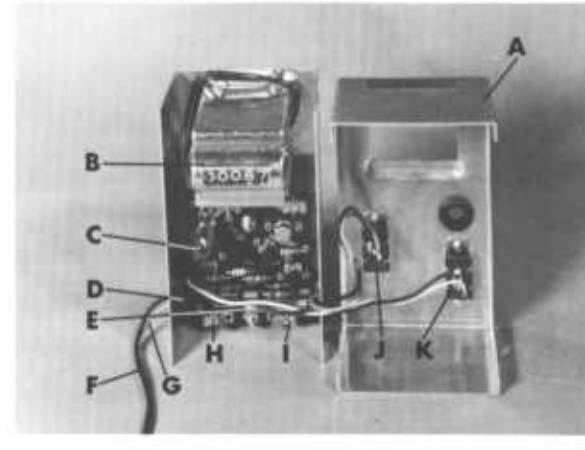


Figure 20.4. — Stewart electronic odometer: *A*, Front cover; *B*, mechanical counter; *C*, test lamp; *D*, rubber grommet; *E*, fuse; *F*, negative battery wire; *G*, positive battery wire; *H*, anemometer ground wire (positive) spring clip; *I*, anemometer wire negative spring clip; *J*, counter "off-on" switch; *K*, test lamp "on" switch.

b. Test battery for power or install a fresh one.
c. Check all lead wires with a continuity tester (see section 19.4).
d. Open counter and replace fuse (E) on the circuit board. Use 3AG, 1½-amp Littlefuse #31201.5, or equivalent.

9. Attach anemometer, spin the cups, and hold the left-hand switch down. This should cause the test lamp to light each time the anemometer contacts close. This is a test of the anemometer circuit.

If the lamp does not light, do any of the following until the trouble is corrected:

a. Check battery polarity.
b. Test battery for power or install a fresh one.
c. Open counter and replace the lamp (C). Use a GS48 lamp, or equivalent.
d. Check anemometer lead wires with a continuity tester.
e. Check anemometer contacts and electrical circuit.

Periodic Maintenance and Troubleshooting

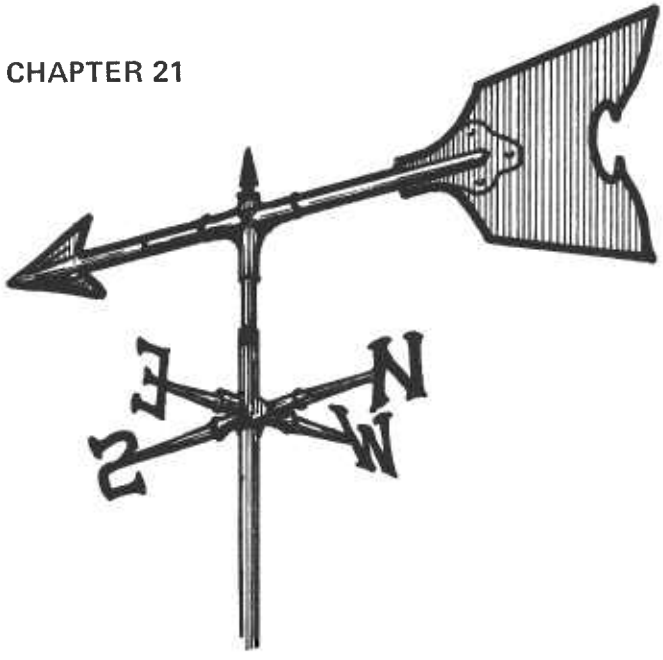
1. Replace battery if required. The decline in brilliance of test lamp can be used as a guide for battery replacement.

2. Before each observation, test instrument by turning power switch "on" and seeing if the counter advances one count. If there is no advance, see item 8, Annual Maintenance.

3. Before each observation, depress switch under test lamp and check to see that lamp lights when anemometer contacts close. If lamp does not light, see item 9, Annual Maintenance.

CROSS REFERENCE: Description 3.1; Installation and Exposure 8.6; Operation 13.1.

CHAPTER 21



WIND VANES

Wind vanes are designed for trouble-free operation over long periods of time. Annual maintenance consisting of cleaning, lubrication, and general refurbishing is usually sufficient to keep an instrument in good operating condition.

Simple, nontransmitting wind vanes require maintenance that will insure free turning in light winds. Inspect for friction, binding, and excessively worn parts.

At least once a year the arrow, or pointer, should be removed from the spindle and cleaned with instrument cleaning solvent. The spindle should be cleaned also and then lubricated with two or three drops of anemometer oil. Inspect all parts for excessive wear and damage such as bent spindle or arrow that could cause binding or irregular turning. If appropriate, repaint worn surfaces (not the spindle) to guard against corrosion and to enhance general appearance.

21.1 STEWART WIND DIRECTION SYSTEM

Annual Maintenance

Wind Vane

Refer to figure 21.1.

1. Loosen the setscrew on the body of the arrow (where the shaft and body meet) and remove the arrow (A) from the spindle (D).

2. Clean the arrow (A) and the wind vane spindle (D) with instrument cleaning solvent.

3. Loosen the four corner screws and remove the front housing cover (B).

4. Clean the commutator ring with instrument cleaning solvent. A small, soft brush or cotton swab will aid this operation.

5. If it has not already been done, note what color wire is attached to each binding post (F).

6. Remove the lead wires one at a time and clean all dirt and corrosion from the ends of the wires as well as from the binding posts.

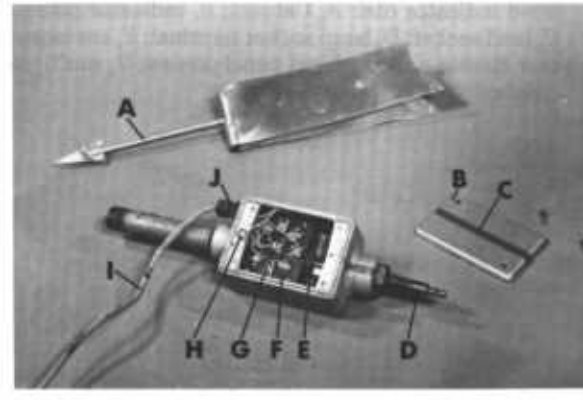


Figure 21.1. — Stewart wind direction system — the electric wind vane component: *A*, Arrow; *B*, front cover; *C*, orientation scribe mark; *D*, spindle; *E*, contact roller; *F*, terminal block binding post; *G*, anemometer wire binding post; *H*, ground connection screw; *I*, multiple conductor cable; *J*, nut and compression sleeve.

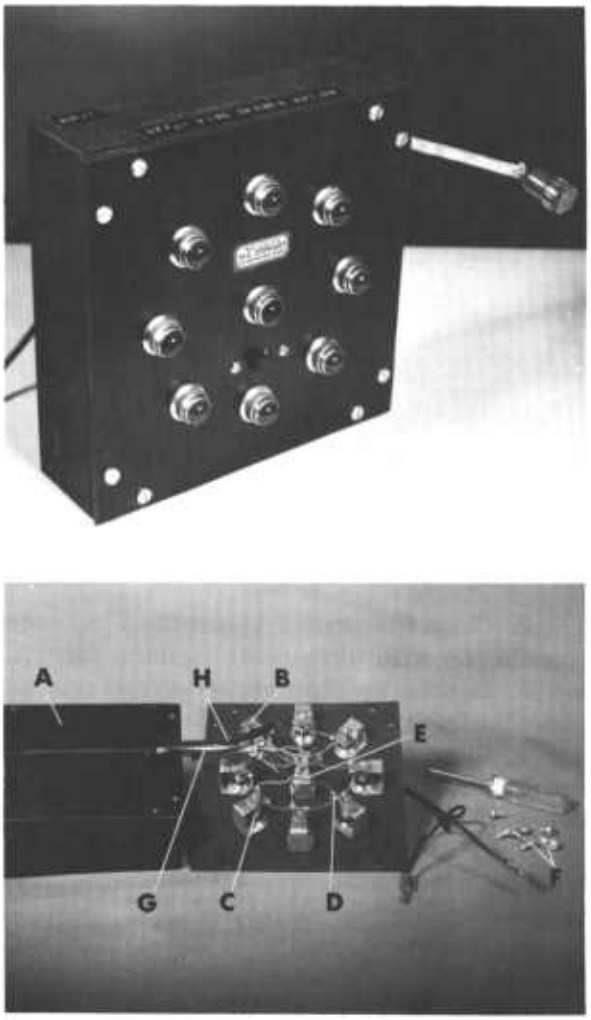


Figure 21.2. — Stewart wind direction system — the wind indicator dial: *A*, Cabinet; *B*, indicator panel; *C*, land socket; *D*, lamp socket terminal; *E*, anemometer flasher unit; *F*, front panel screws; *G*, multiple conductor cable; *H*, battery cable.

7. Replace wire leads and tighten all connections.

8. Inspect front housing cover gasket. If it is worn, torn, or otherwise damaged and will no longer provide a moistureproof seal, replace it with a new one cut from similar material.

9. Replace front housing cover.

10. Put three drops of anemometer oil on the spindle (D), just above the top bearing.

11. Replace arrow and tighten set screw.

Wind Direction Indicator.

Refer to figure 21.2.

1. If battery is attached, detach and discard.

2. Loosen corner screws (F) and remove front panel (B).

3. Clean dust from interior of cabinet (A).

4. Inspect electrical connections (D) and remove any dirt or corrosion.

5. Repair loose connections by soldering them in place. Use rosin-core solder.

6. Attach a fresh 6-volt lantern battery; spin the attached wind vane arrow and check to see that all indicator lamps light.

7. If a lamp does not light, replace it with one that is known to be good.

8. To replace a lamp, first remove the protective lens by turning counterclockwise. Grip lamp with a short piece of rubber tubing and also turn counterclockwise. Replacement lamp should be GE #46, or equivalent, and have a blue bead just below the element. Be sure to replace this protective lens after installing a new lamp.

9. After installing each new lamp, spin wind vane arrow again. If lamp still fails to light, check for breaks and shorts in wires and connecting cable (see section 19.4).

10. When all lamps are "on," replace front cover.

Periodic Maintenance

1. The passage of current through the contacts retards both the buildup of corrosion and the accumulation of dust particles and oil film on the contact surfaces. For this reason, it is suggested that the indicator lamp be left "on" a good portion of each day.

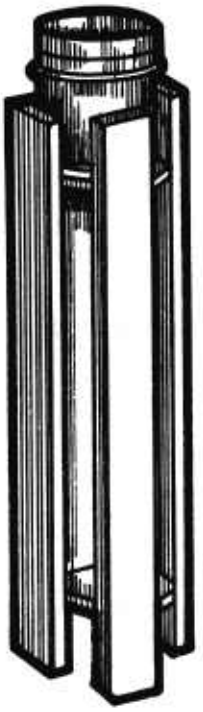
2. Whenever lamps become dim, replace the battery.

CROSS REFERENCE: Description 3.2; Installation and Exposure 8.7.

21.2 OTHER WIND DIRECTION SYSTEMS

Other wind direction systems exist that are capable of supplying data for fire-weather purposes (fig. 21.3). Some of these systems are combined with an anemometer to supply both speed and direction data. Maintenance of these units is often complicated and many are sealed units requiring factory service. Follow manufacturer's instructions regarding maintenance of such instruments.

Figure 21.3. — Wind direction system using generator type anemometer and contacting wind vane. Wind direction is indicated by lights; windspeed by arrow on dial.



RAIN GAGES

Maintenance requirements for nonrecording rain gages are similar; thus, they are treated as a group in this section. Recording rain gages, on the other hand, have differing maintenance requirements depending on type, make, and often even on the model. If at all possible, the instruction book provided with the instrument should be referred to before attempting any major maintenance on recording rain gages.

22.1 NONRECORDING RAIN GAGES

Nonrecording rain gages are perhaps the easiest of all fire-weather station instruments to maintain. Nevertheless, the few simple requirements listed below should be followed for accurate measurement of precipitation.

Annual Maintenance

1. Carefully check both the measuring tube and the overflow cylinder for leaks and dents. Repair or replace these components as necessary.

2. Check the rim of the collector, or funnel. It should be perfectly round (except the small wedge-shaped gage), knife-edge sharp, and free of nicks, dents, and other irregularities. Repair or replace as necessary.

3. Thoroughly clean inside of measuring tube using hot water and a brush.

4. Check the measuring stick. If markings are faded or if stick is dirty, clean or replace.

5. On the plastic models that have graduated cylinders it may be necessary to occasionally renew markings. This can be done by using the techniques described for thermometers (see section 16.2).

Periodic Maintenance

1. Check firmness level and plumb of rain gage support. Repair as necessary.

Figure 22.1. — Checking level on standard rain gage.

2. Keep top of gage level. Check periodically by laying a carpenter's level across the top of the collector (fig. 22.1). Adjust as necessary.

3. Keep overflow cylinder and measuring tube free of dirt and debris. Do not allow debris to collect in funnel. Empty measuring tube after each measurement.

4. Do not handle the graduated part of the measuring stick with hands. Always hold stick at the upper end.

5. During freezing weather, remove funnel and measuring tube to prevent ice damage.

CROSS REFERENCE: Description 4.1; Installation and Exposure 8.8; Operation 14.1-14.3.

22.2 TIPPING BUCKET RAIN GAGE

Refer to figure 22.2.

Specific maintenance requirements will vary depending on model and manufacturer. The instrument manual provided by the manufacturer should be consulted for detailed information on maintenance and calibration.

Annual Maintenance

1. Discontinue use of tipping bucket rain gage in freezing weather unless the instrument contains a heating unit.

2. Check rim of collector (A). It should be perfectly round and free of nicks, dents, and other irregularities. Repair as necessary.

3. Remove storage container (E) and then clean and check for leaks.

4. Remove collector (B) and clean all moving parts with a soft brush and instrument cleaning solvent. Be sure to use a cleaner that does not attack painted surfaces.

5. Check all parts for wear. Replace worn parts.

6. Check tipping bucket (C) action. Eliminate any binding.

7. Lubricate sparingly the pivots of the bucket and the V bearing in the support bracket. Use a light, nongumming instrument oil.

8. Do not attempt to adjust position of the calibration stop screws (D) located in the supporting bracket below the cups unless complete calibration instructions are available. Calibration is set at the factory and usually does not require modification unless the instrument has been subjected to very rough handling.

Figure 22.2. — Tipping bucket rain gage: *A*, Collector rim or knife edge; *B*, collector; *C*, tipping bucket; *D*, calibration stop screw; *E*, water storage container; *F*, cable to recorder.

Periodic Maintenance

1. Keep collector free of debris.

2. Wipe out tipping bucket with a clean cloth weekly.

3. Wipe bucket pivots and support bracket V bearing with oily cloth weekly.

4. Periodically check recorded precipitation with measured amount of water in storage container.

Recorder Maintenance

A variety of recorders can be used with tipping bucket rain gages. Refer to the appropriate instruction manual for maintenance requirements. If a drum type reader is used, maintenance instructions given in sections 18.3 and 18.4 may apply.

CROSS REFERENCE: Description 4.1; Installation and Exposure 8.9.

22.3 WEIGHING RAIN GAGE

Refer to figure 22.3.

Maintenance requirements of the weighing rain-gage pen, pen arm assembly, chart drive assembly, and clock are identical to the requirements prescribed for similar components of the hygrothermograph. For this reason they are not repeated here (see chapter 18).

General Maintenance

The following general maintenance items should be performed at the end of each season's use or every 6 months if the gage is operated year-round. Refer to manufacturer's instrument manual for detailed instructions.

1. Remove collector and outer case. Clean all moving parts thoroughly using instrument cleaning solvent applied with a soft brush. Do not use solvents that attack painted surfaces.
2. Check linkage system, spring, and other moving parts for wear and other evidence of binding or excessive friction.
3. Sparingly lubricate bearings of all moving parts (except chart drive assembly) with a light, nongumming instrument oil.
4. Scrub bucket inside and out to remove accumulated dirt, grime, and corrosion.
5. Check level of fluid in dash pot (I). Add necessary dash pot fluid to bring level to within one-fourth inch of the top of the dash pot. Dash pot fluid is available from most instrument supply houses or directly from the rain gage manufacturer.
6. Check weighing mechanism for accuracy by placing 29.0 ounces in the bucket for each inch of rain. (Bendix-Friez Model 775CS requires 72.5 ounces for each inch of rain.) Make necessary thumbscrew (D) adjustments to bring pen to 1-inch level on chart. Rain gage calibration weights are available from weather instrument supply houses or from rain gage manufacturers (fig. 22.4).
7. Refer to sections 18.1 to 18.4 for general maintenance requirements for pen, pen arm assembly, chart drive assembly (B), and clock.

Calibration

If the accuracy of a weighing rain gage is questioned, do the following before trying recalibration:

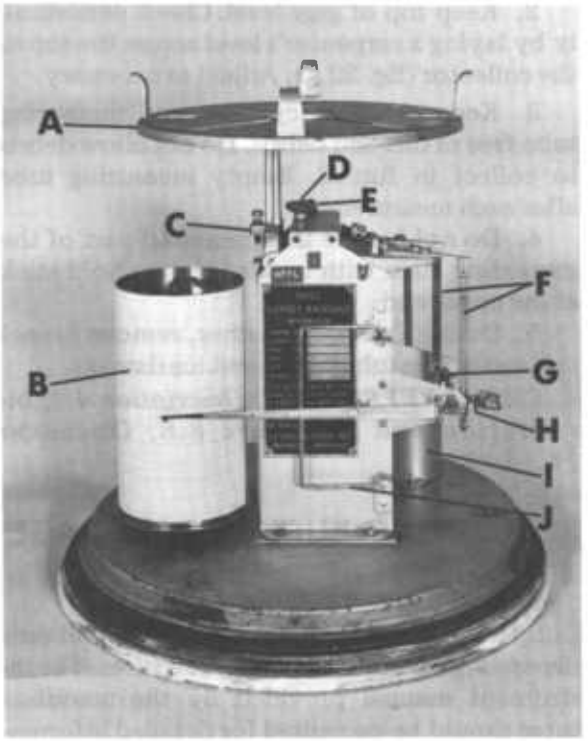


Figure 22.3. — Weighing rain gage — weighing and recording assembly: *A*, Weighing platform; *B*, chart drive assembly; *C*, stop screw; *D*, spring adjusting screw; *E*, thumb nut (red); *F*, linkage assembly; *G*, magnification bar (first traverse); *H*, magnification bar (second traverse); *I*, dash pot; *J*, pen lifter.

Figure 22.4. — Calibration weights for recording rain gages.

1. Check the chart installation. The chart must be firmly seated against the flange along the lower end of the chart drum (B).

2. Check chart drum (B). It must be properly seated on the spindle or arbor. The external gears must be meshed.

3. Check to see that there are two spacing washers between the base of the gage and the large stationary gear at the base of the spindle or arbor.

4. Check mechanical condition of the gage. Look especially for points of undue friction in the linkage.

After having checked the above items, proceed to check present calibration as follows:

5. Place bucket on weighing platform (A).

6. Zero the pen arm using the red knurled thumb nut (D). The pen should be on the zero line of the chart.

7. Add to the bucket weights (fig. 22.4) the equivalent of 1 inch of rainfall (29.0 ounces). Add 12 weights, one at a time, and note the chart value indicated as each weight is added. If the chart values observed are incorrect for the weight added, the instrument is in need of calibration.

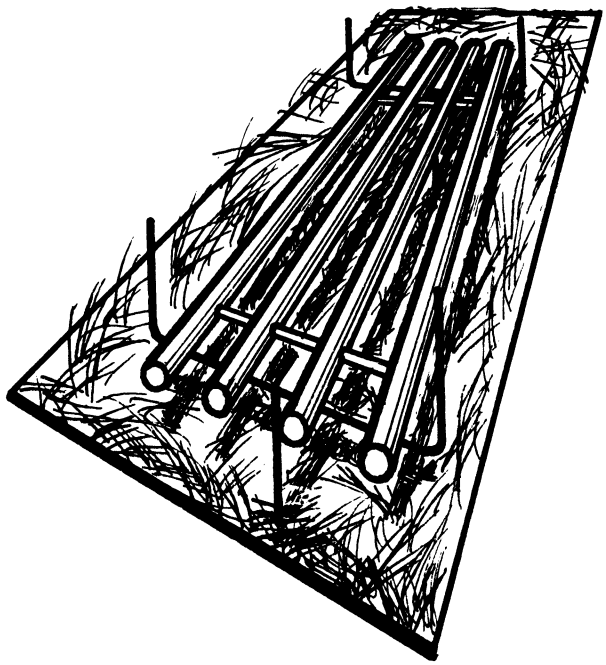
If there is insufficient or nonuniform motion of the pen over the first and/or second inch of chart when the bucket and weights are added, but correct or uniform motion of the pen is obtained thereafter, then the spring probably needs replacement.

This malfunction of the spring can be checked by observing the action of the spring when the empty bucket and the weights are added to the platform. After the bucket and a weight are added, the spring should have started to open. If no space can be observed between each effective coil, the spring is defective and should be replaced.

Further calibration should not be attempted without the detailed instructions and schematic diagrams provided by the manufacturer. These are either contained in the instrument manual (Bendix-Friez) or are available by request from the manufacturer (Belfort).

CROSS REFERENCE: Description 4.1; Installation and Exposure 8.9; Operation 14.4.

CHAPTER 23



FUEL MOISTURE STICKS

A fuel moisture stick should be discarded after one season's use (more often in areas of rapid weathering); hence, there is no annual maintenance requirement. While in use, a few simple maintenance items require the observer's attention.

Dirt, oil, and dust add to the weight of the stick and can interfere with normal moisture changes of the stick. The stick, therefore, should be kept clean. Prior to each weighing, dust the stick with a soft, clean paint brush. Do not brush the stick if it is wet. Wait until it is dry.

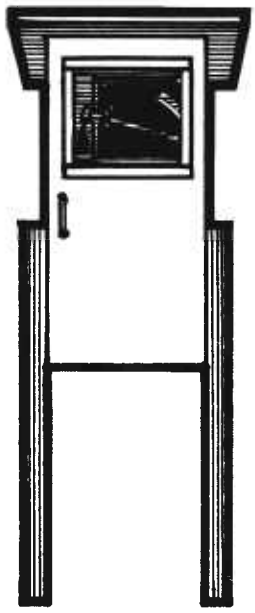
Cover hands with clean gloves or use a clean cloth or a clean piece of hard-finish paper to pick up stick for weighing. Handling stick with bare hands might contaminate it with oil and dirt.

A properly installed duff bed will prevent mud from splashing up on the stick during heavy rains. In the event that the stick does become mud splattered, allow mud to dry and then brush off (do not rub in) the dirt.

Do not remove the metal hook at the end of the stick as its weight is included in the 100-gram dry weight of the stick. Similarly, guard against scratches, chips, breaks, etc. If they occur, replace with a new stick.

CROSS REFERENCE: Description 5.1; Installation and Exposure 8.10.

CHAPTER 24



FUEL MOISTURE SCALES

When properly installed in a weatherproof shelter, the fuel moisture scale requires minimum maintenance. Annual cleaning and periodic calibration checks are the major items of concern.

Specific maintenance instructions for the scales most often used to weigh fuel moisture analogs are presented in the following sections.

24.1 THE APPALACHIAN SCALE

(Forester Model 9X100, Bendix-Friez)

Refer to figure 24.1.

Annual Maintenance

1. Disassemble scale and clean all parts using an instrument cleaning solvent that is nonflammable.

2. Check the beam (E) for straightness. If bent, repair or replace.

3. Check wire hook (J) at rear of beam. It should be well-formed, straight, and should swing free.

4. Clean and check the bearing hole on front (C) and rear (D) pivot plates. If excessively worn, replace.

5. Check the beam pivot shaft. It must be straight. If bent or excessively worn, repair or replace.

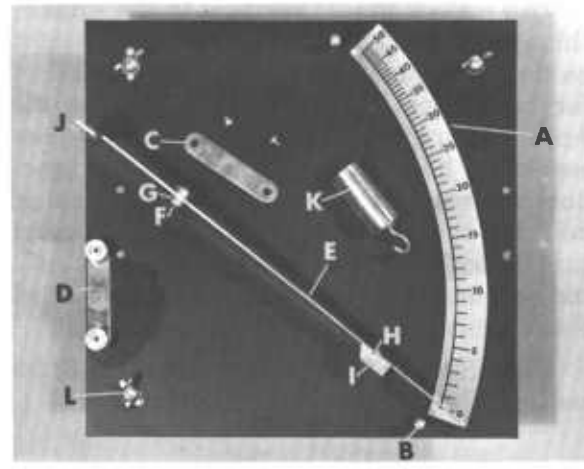


Figure 24.1. — The Appalachian scale; *A*, Backplate with calibrated scale; *B*, beam stop plug; *C*, front pivot plate; *D*, rear pivot plate; *E*, beam; *F*, beam pivot shaft; *G*, beam pivot shaft spacer; *H*, sliding weight setscrew; *I*, sliding weight; *J*, beam link or hook; *K*, 100-gram test weight; *L*, mounting bracket wing nut.

6. Reassemble, mount in shelter; check first the shelter and then the scale for level. Both must be square and plumb.

7. Check adjustment. The sliding weight (I) must be movable by moderate hand pressure. Adjust by using the set screw (H) on top of sliding weight. Set sliding weight at 100 and

hang 100-gram test weight on hook at end of pointer. Pointer should indicate zero on the graduated arc scale. If the pointer does not indicate zero, loosen wing nuts (L) and adjust entire backplate (A) up or down. Do not adjust zero with sliding weight on beam as this, in effect, changes ovendry weight of the fuel stick.

Periodic Maintenance

1. Dust with soft brush whenever a buildup of dirt is visible.
2. Occasionally check both shelter and scale for level and plumb.
3. Prior to each use of scale, check calibration with test weight (K). Make only very fine adjustments with sliding weight (see item 7, above).

CROSS REFERENCE: Description 5.3; Installation and Exposure 8.11; Operation 15.1.

24.2 REGION 6 SCALE

This scale is almost identical to the Appalachian scale except that it has no sliding weight on the beam. Maintenance instructions, except for calibration, are as given above for the Appalachian scale. To calibrate, hang 100-gram weight on hook at end of beam. If the beam does not read zero, loosen the wing nuts that hold the backplate to the mounting plate and turn the scale on the upper right-hand bolt until the pointer reads zero. Tighten wing nuts and check pointer. Repeat until zero is obtained.

CROSS REFERENCE: Description 5.3; Installation and Exposure 8.11; Operation 15.1.

24.3 WILLIAMS POCKET FIRESTICK MOISTURE SCALE

Refer to figure 24.2.

The primary maintenance requirement of this sturdy little instrument is periodic cleaning. Apply instrument cleaning solvent and use a toothbrush to scrub away accumulated dirt, especially from the threads on the balance beam (D) and the handle (A).

The central knife edge (E) of the scale is spring-loaded to protect it from injury, and is adjusted to move freely under the screw

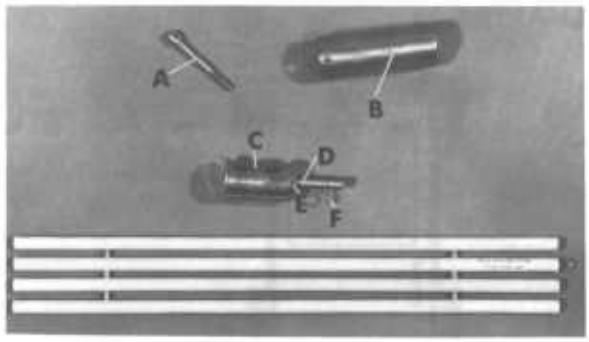


Figure 24.2. — Williams Pocket Firestick Moisture Scale: *A*, Handle and locking screw; *B*, cover and 100-gram test weight; *C*, balance weight; *D*, balance beam; *E*, knife edge; *F*, hook.

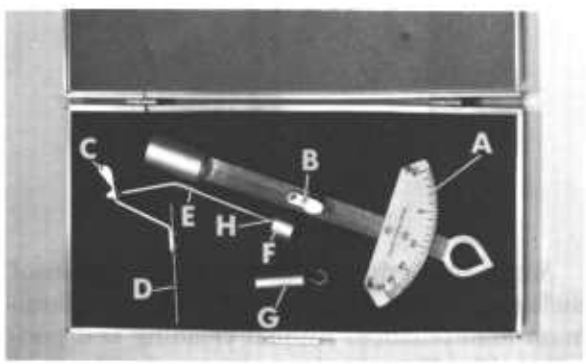


Figure 24.3. — Forester 9X120 portable fuel moisture scale, Chisholm model: *A*, Scale; *B*, scale beam support bracket; *C*, fuel stick suspension loop; *D*, pointer; *E*, scale beam shaft; *F*, scale beam weight; *G*, 100-gram test weight: *H*, scale beam weight adjustment nut.

heads. This adjustment never needs to be changed and is correct when it leaves the factory.

The cover (B) of the scale also serves as a 100-gram test weight. For this reason do not engrave on it, stick plastic marking tape on it, or otherwise add to or subtract from its original weight.

CROSS REFERENCE: Description 5.3; Operation 15.3.

24.4 PORTABLE FUEL MOISTURE SCALE—CHISHOLM MODEL

Refer to figure 24.3.

To check calibration, hang the 100-gram test weight on the loop (C) provided, hold the

scale level, and check to see that pointer (D) indicates zero on the scale (A). If pointer does not indicate zero, loosen nut (H) at weight end of the scale beam and adjust weight until zero is obtained. Tighten nut and recheck. Always be sure to hold the scale level.

CROSS REFERENCE: Description 5.3; Operation 15.2.

24.5 TRIPLE BEAM BALANCE

Refer to figure 24.4.

Annual Maintenance

1. Dust thoroughly with a soft, clean brush. Wash top of platform (A) if necessary.

2. Remove the bearing cover plates (E and F). Blowing the bearings out with a dry air blast is the recommended method of cleaning. On older models it may be necessary to use a toothbrush to remove stubborn dirt.

3. Clean any accumulated debris from the magnet faces located under the platform (A) in the balance cup (B). Press a piece of Scotch tape against the magnet face to pick up attracted material which might interfere with the damping vane.

4. Replace the bearing plates. Take care not to damage the bearings or dull the knife edges.

5. Check knife edges, especially on older models. If dull, the scale will react sluggishly. Sharpen or replace dull knife edges.

Periodic Maintenance

1. Remove dust from top of platform before each use.

2. Periodically check the scale's balance since foreign material may accumulate on the platform beams and cause a slight change in the balance position. Do this on a fairly flat and level surface.

With an empty pan and all the weights at zero, the pointer should oscillate the same number of divisions above and below the center line, or zero, and eventually come to rest at zero. Very lightly tap a bearing cover so the pointer will not stop prematurely.

If the scale does not balance, adjust the knurled adjusting knobs (two knobs act together as lock nuts on older models.) Screw the knobs out if the pointer is low, screw in if the pointer is high. When proper adjustment is obtained, lock the nuts tightly together, then recheck the pointer.

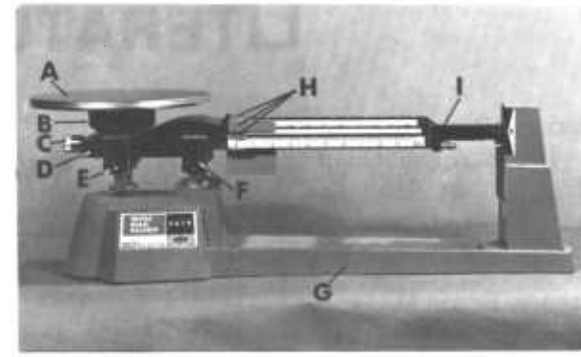


Figure 24.4. — Triple beam balance: *A*, Platform; *B*, balance cup; *C*, knurled adjustment knob; *D*, friction plate; *E*, bearing cover; *F*, bearing cover; *G*, base; *H*, poise (sliding weights); *I*, beam.

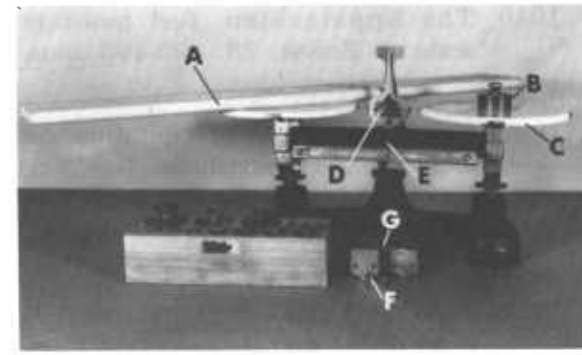


Figure 24.5. — Harvard balance: *A*, One-half-inch fuel sticks; *B*, 100-gram weight; *C*, pan; *D*, knurled adjusting knob; *E*, main bearing; *F*, main bearing cover plate; *G*, lock.

3. Check the zero balance whenever the balance is moved since it will be affected by a change in the inclination of the working surface.

CROSS REFERENCE: Description 5.3; Operation 15.4.

24.6 HARVARD BALANCE

Refer to figure 24.5.

Maintenance instructions for the Harvard balance are similar to those for the triple beam scale.

CROSS REFERENCE: Description 5.3; Operation 15.5.

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APPENDIX

FIRE-WEATHER STATION CONDITION REPORT

INSTRUCTIONS: This form may be used for several purposes--(1) as a station location record--Section 1; (2) as an equipment inventory record--Section 2; (3) as an inspection report--Section 3; and (4) as an observer self-training guide--Section 3.

SECTION 1 - STATION LOCATION RECORD

Enter information or check (✓) appropriate items.

Station name_____ Station number_____ Year established_____

Operating agency_____ Local unit_____ Operating season_____

State_____ County_____ T_____ R_____ Section_____

Topography: Flat or gently rolling_____, hilly or broken_____, mountain valley_____, mountaintop_____, mountain slope_____.

Aspect: N_____, S_____, E_____, W_____.

SECTION 2 - STATION EQUIPMENT RECORD

Enter information or check (✓) appropriate items.

Instrument shelter: Cotton region_____, other_____
Maximum-minimum thermometer: Standard_____, other_____
Psychrometer: Electric fan_____, other_____
Hygrothermograph: Make_____, chart period_____
Anemometer: Make_____, model_____
Wind counter: Type_____, make_____
Wind vane: Type_____, make_____
Wind direction indicator: Type_____, make_____
Rain gage (nonrecording): Forest Service type_____, Weather Service type_____
Recording rain gage: Type_____, make_____
Fuel moisture analog: 1/2-inch sticks_____, other_____
Fuel moisture scale: Type_____, make_____

SECTION 3 - INSPECTION REPORT AND SELF-TRAINING GUIDE

Enter an X in either Yes or No column according to condition. Explain all No entries, by number, in REMARKS.

	Yes	No
Station Location		
1. Adequately represents area of concern.		
2. Allows for long term operation.		
3. Accommodates instrument exposure requirements.		
a. Dust sources at least 100 ft. on windward.		
b. Moisture sources at least 100 ft. on windward.		
c. Large reflective surfaces a distance equal to their height away.		
d. Paved or black topped areas at least 50 ft. away.		
e. Large obstructions at least a distance equal to their height away.		
f. Distinct changes in topography lacking.		
Station Layout		
4. Allows free flow of air.		
5. Allows full sun exposure.		
6. Tall vegetation cleared for 20 ft. around station.		
7. All vegetation on station grounds less than 4 in. high.		
8. Station grounds not irrigated.		
9. Fence of open type construction.		
10. Fence less than 4 ft. high.		

	Yes	No
Instrument Shelter		
11. Cotton region or other approved design.		
12. Shelter floor 4 ft. above ground.		
13. Shelter firmly secured to stand.		
14. Stand firmly secured to ground.		
15. Installation level and plumb.		
16. Door faces away from sun.		
17. Painted glossy white, inside and out.		
18. Inside clean of dirt and dust.		
19. Only temperature sensitive instruments in shelter.		
Standard Maximum-Minimum Thermometers		
20. Exposed in instrument shelter.		
21. Townsend Support securely mounted on crossboard.		
22. Townsend Support spinning clamp on bottom.		
23. Minimum bulb on left, in top clamp.		
24. Minimum bulb 5° below horizontal.		
25. Maximum bulb on left, in lower clamp.		
26. Maximum bulb 5° above horizontal.		
27. Thermometers clean and legible.		
28. Thermometer columns intact, not separated.		
29. Maximum column does not "retreat."		
30. Minimum index floats freely.		
31. Maximum spins freely in its clamp.		

Fan Psychrometer

		Yes	No
32.	Exposed in instrument shelter.		
33.	Firmly mounted, clear of maximum thermometer.		
34.	Wet bulb wick clean.		
35.	Wet bulb wick extends 1 in. above and below bulb.		
36.	Thermometers clean and legible.		
37.	Thermometers agree within 1/2° when both bulbs dry.		
38.	Water and container present and clean.		
39.	Polarity of battery wires correct.		
40.	Fan operates at top speed, batteries fresh.		

Hygrothermograph

41.	Exposed in instrument shelter.		
42.	Clear of maximum thermometer.		
43.	Hair element intact and clean.		
44.	Temperature element dust free.		
45.	Pens inking properly.		
46.	Both pens indicate the same chart time.		
47.	Chart time correct.		
48.	Range and spread of pen arms appear correct.		
49.	Current chart values agree with psychrometer values.		

Anemometer

50.	Located for representative readings.		
51.	Pole adequately supported, windfirm.		
52.	Lightning protection adequate.		
53.	Cups exposed at 20-ft. standard height.		
	a. Level ground, low cover-- 20 ft.		
	b. High ground in rolling topography--20 ft.		
	c. Low ground in rolling topography--20 ft. plus average depth of low spot.		
	d. Dense ground cover--20 ft. plus average height of cover.		
	e. Scattered ground cover--20 ft. plus one-half average height of cover.		
	f. Sparse ground cover--20 ft. plus one-third average height of cover.		
54.	Periodic height adjustment possible.		
55.	Easy access to anemometer provided.		
56.	Cups turn freely in light winds.		

Mechanical Wind Counter

57.	Lightning protection adequate.		
58.	Weatherproof wire used.		
59.	Polarity of battery wires correct.		
60.	Voltage and line length in proper balance.		
61.	Counter advances one digit at a time.		
62.	Timer runs for exactly 10 minutes.		
63.	Counter <u>not</u> installed in temperature shelter.		

Wind Vane and Indicator

		Yes	No
64.	Lightning protection adequate.		
65.	Vane oriented with true north.		
66.	Vane turns freely in light wind.		
67.	Weatherproof wire used.		
68.	Indicator readout agrees with vane direction.		
69.	Polarity of battery wires correct.		
70.	Indicator not installed in temperature shelter.		

Standard Rain Gage

71.	Level and plumb.		
72.	Gage free of dents, leaks, debris.		
73.	Stand firmly attached to ground.		
74.	Top of gage 36 in. above ground.		
75.	45° angle from top of gage clears obstacles.		
76.	Measuring stick clean and legible.		

Recording Rain Gage

77.	Firmly mounted to ground.		
78.	Level and plumb.		
79.	Pen inking properly.		
80.	Chart time correct.		
81.	Pen properly zeroed.		
82.	Calibration appears correct.		
83.	Collector free of dents and debris.		
84.	Pail clean, free of leaks.		

Fuel Moisture Sticks

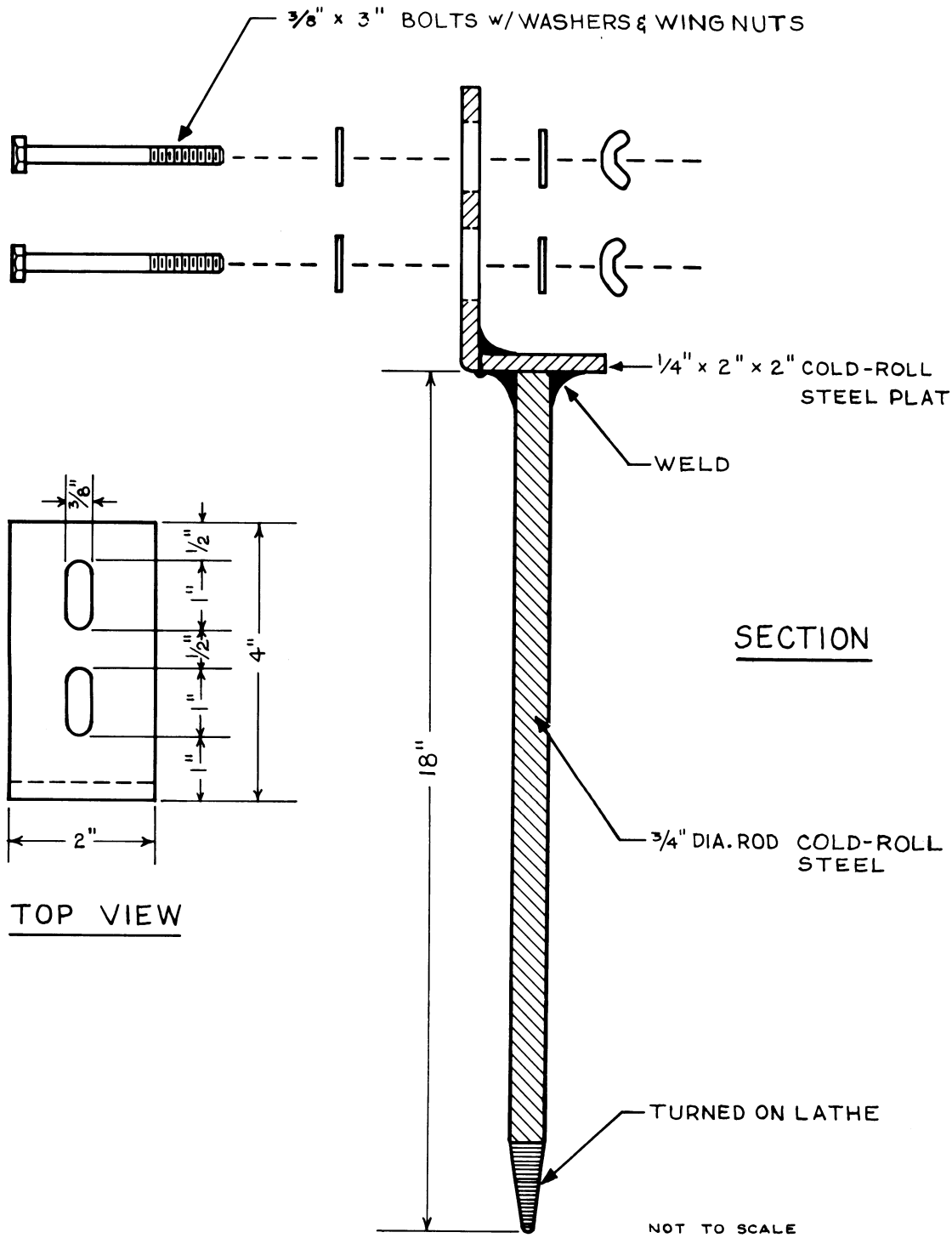
85.	Duff bed 36 in. square, 2 in. deep.		
86.	Duff bed over mineral soil, no humus		
87.	Duff bed free of living vegetation.		
88.	Duff bed at ground level, not in pit.		
89.	Stick hook end north, nails down.		
90.	Stick clean and undamaged.		
91.	Wire racks 10 in. above duff bed.		
92.	Wire rods of galvanized wire.		

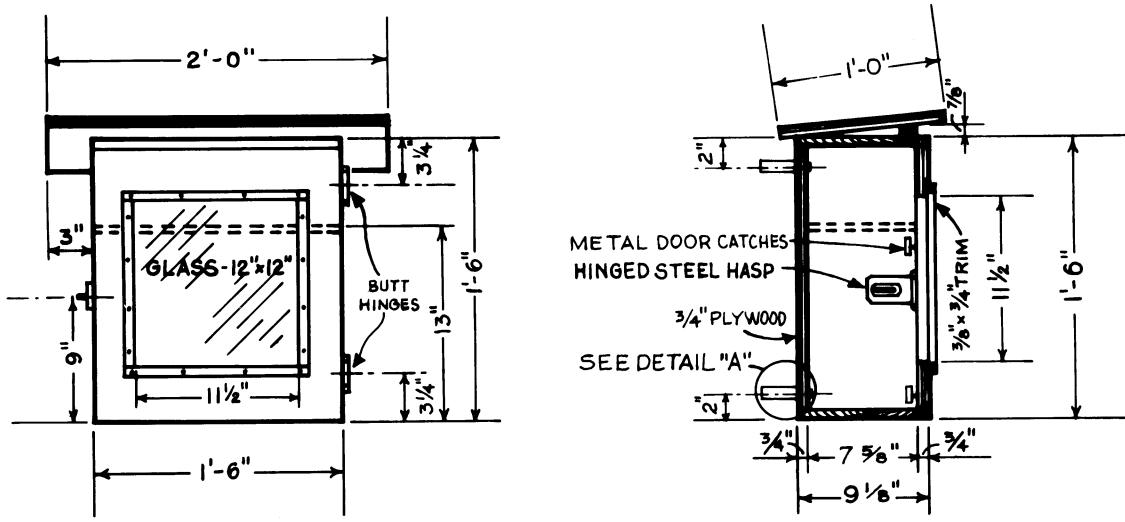
Fuel Moisture Scale

93.	Shelter firmly mounted to ground.		
94.	Shelter level and plumb.		
95.	Shelter weatherproof, in good repair		
96.	Scale installed properly, level and plumb.		
97.	Scale clean, dust free.		
98.	Scale balances at zero.		
99.	Scale balances at 100 grams with test weight.		
100.	Balance action free, doesn't bind.		

REMARKS: _____

INSTRUMENT SHELTER ANCHOR PIN



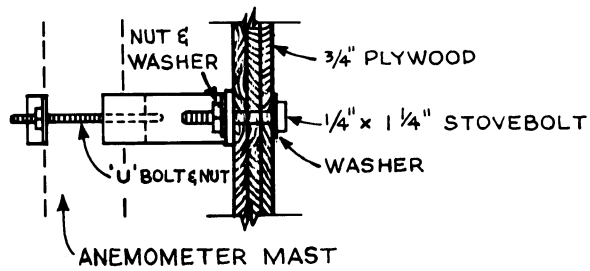


SCALE: 1" = 1'-0"

FRONT VIEW

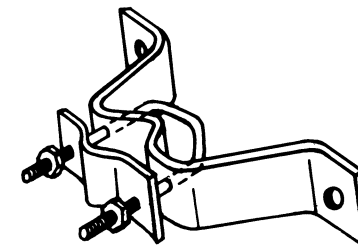
SECTION

WALL MOUNT ATTACHMENT



DETAIL "A"

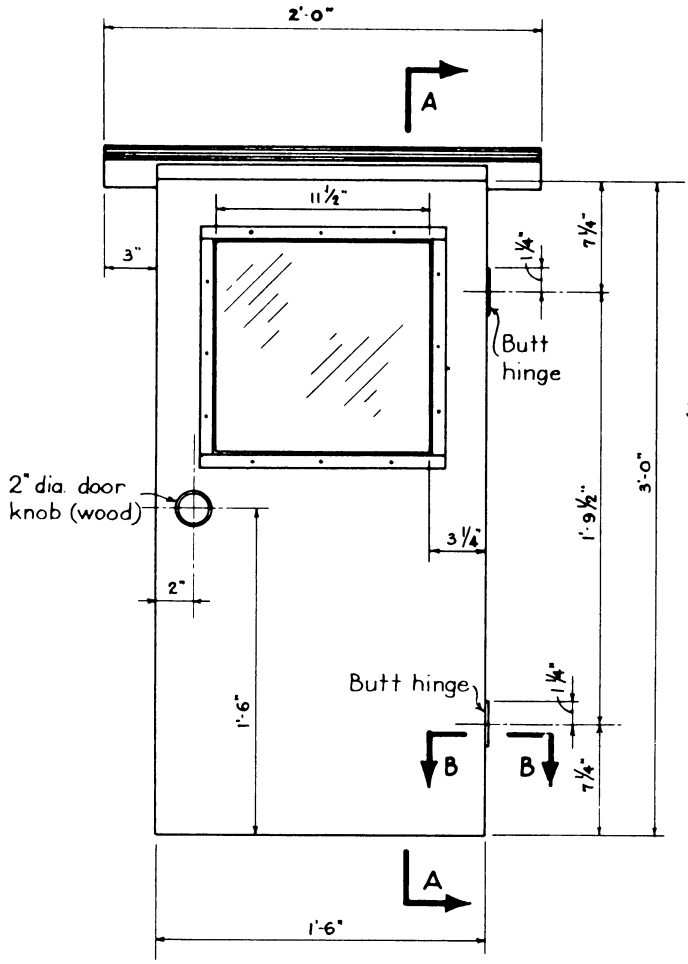
4" WALL MOUNT



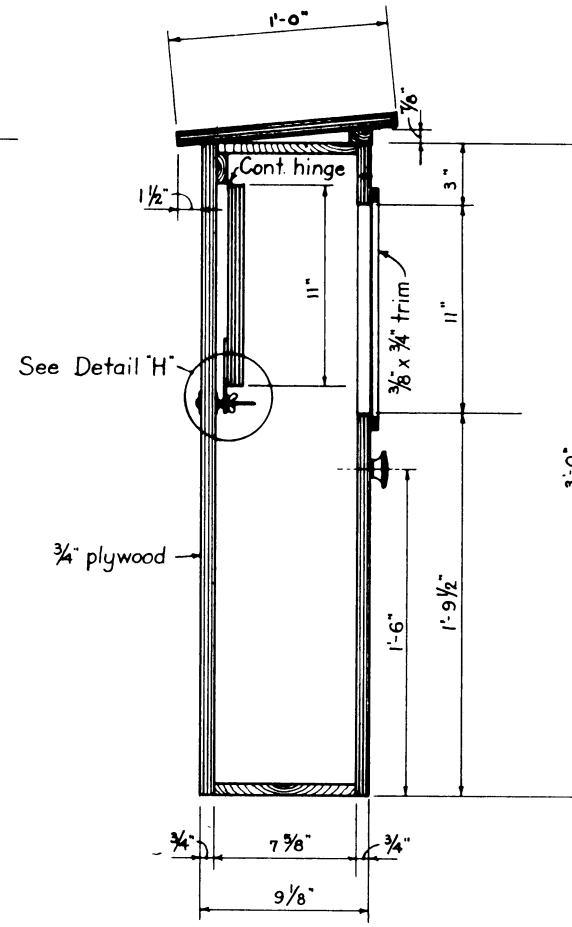
3-D DRAWING

NOT TO SCALE

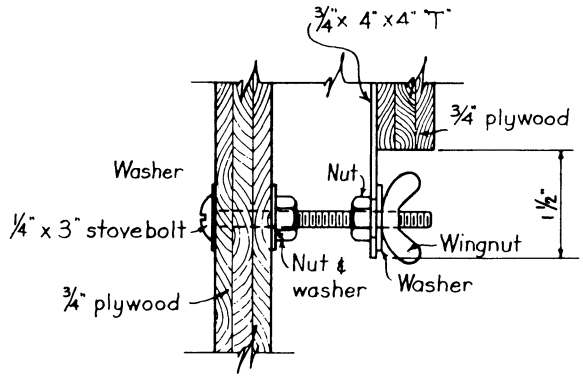
WEATHER STATION ACCESSORY SHELTER



FRONT ELEVATION



SECTION A-A



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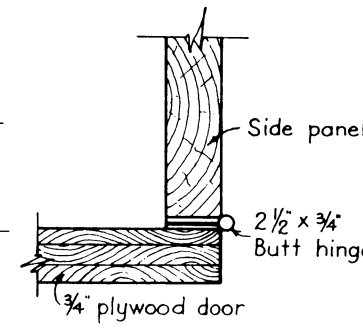
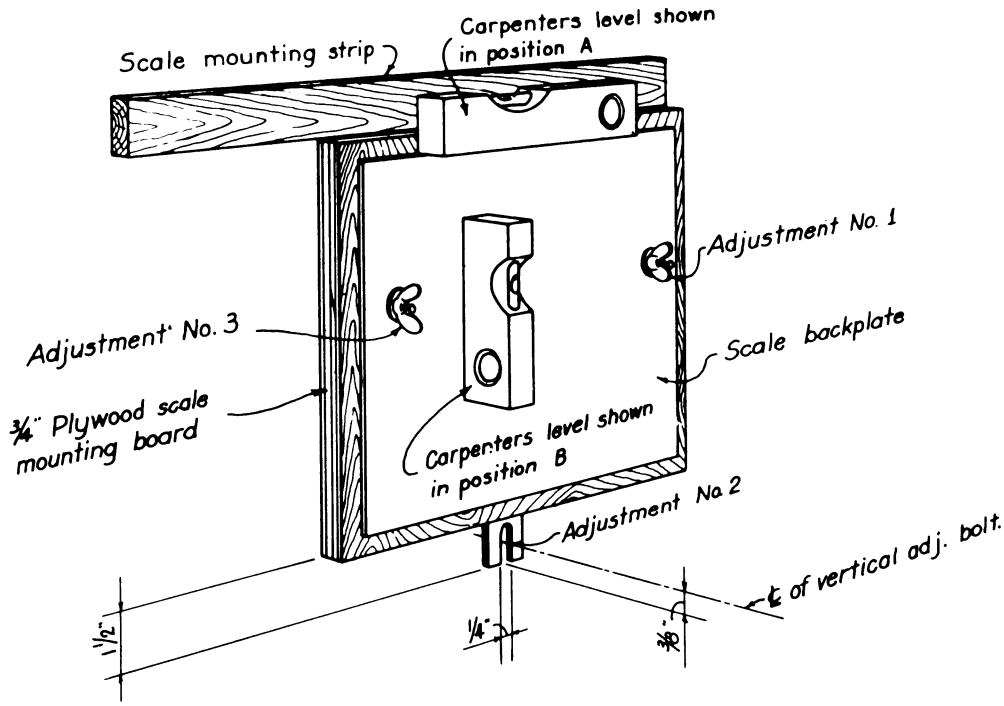
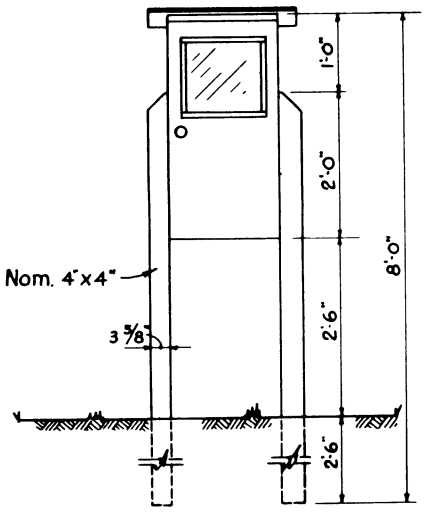


SECTION B-B

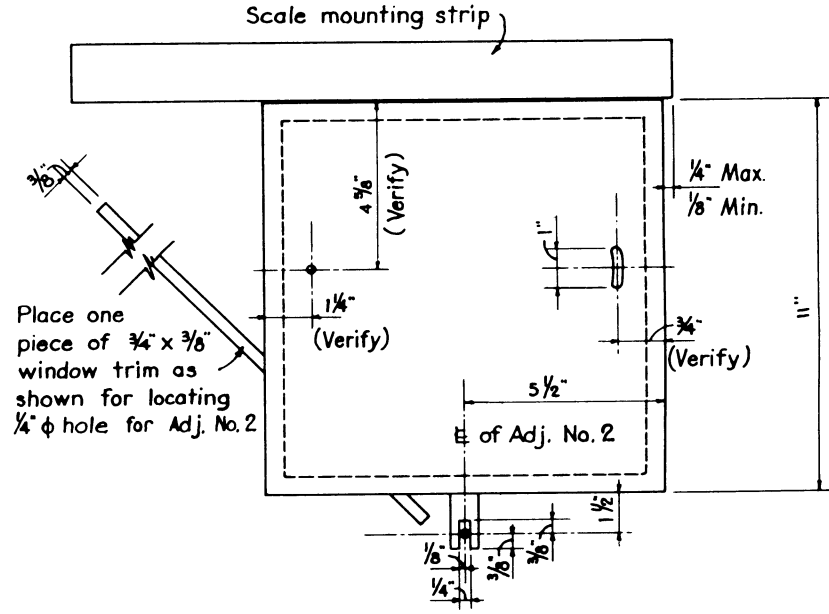
APPALACHIAN SCALE SHELTER



PERSPECTIVE VIEW
SCALE LEVELING DETAIL

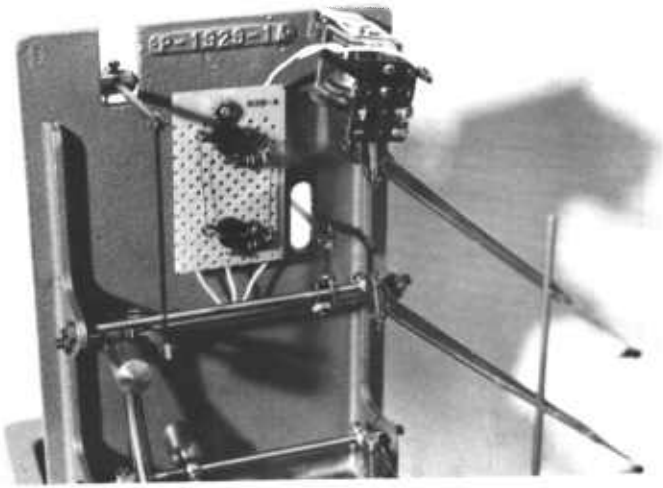


SHELTER MOUNTING DETAIL



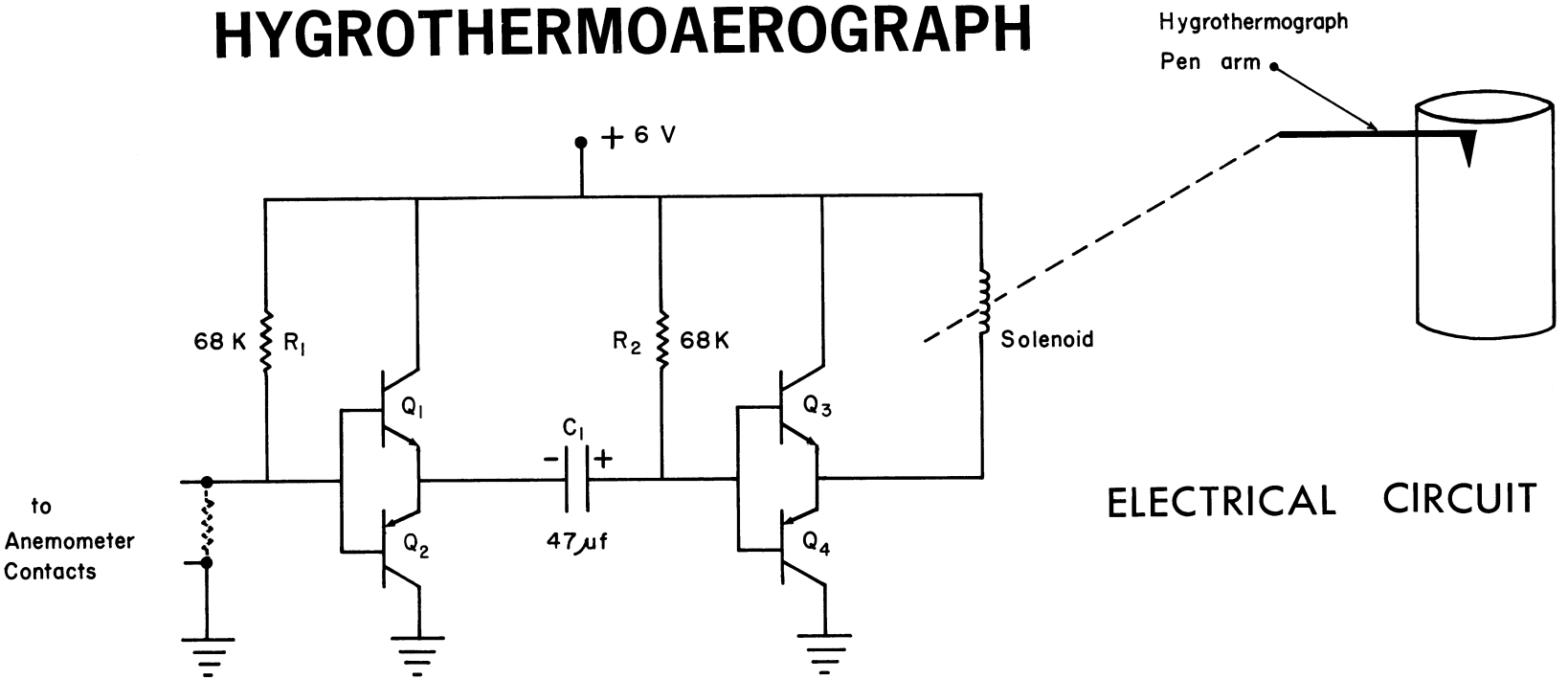
MOUNTING BOARD DETAIL

HYGROTHERMOAEROGRAPH



HYGROTHERMOGRAPH MODIFICATION

HYGROTHERMOAEROGRAPH



Parts List

1 – Solenoid	–	D.C. Relay; 200 ohm w/silver contacts. (SIGMA-200 or equivalent.)
2 – Resistors	–	R_1 and R_2 = 68k, ± 10%; 1/2 watt.
1 – Capacitor	–	C_1 = 47µf, 10 volt D.C.; ± 10%.
1 – Battery	–	6 volt, lantern type.
4 – Transistors	–	Q_1, and Q_3; NPN FAIRCHILD S 7581 or equivalent.
		Q_2, and Q_4; PNP G.E. 2N1303 or equivalent.

INDEX

R

S

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WS TA B-0-5A
(11-73)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RELATIVE HUMIDITY and DEW POINT TABLE

Pressure 23 Inches of Mercury

For use at elevations between 6,101 and 8,500 feet above sea level
(In Alaska use at elevations between 5,701 and 7,900 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

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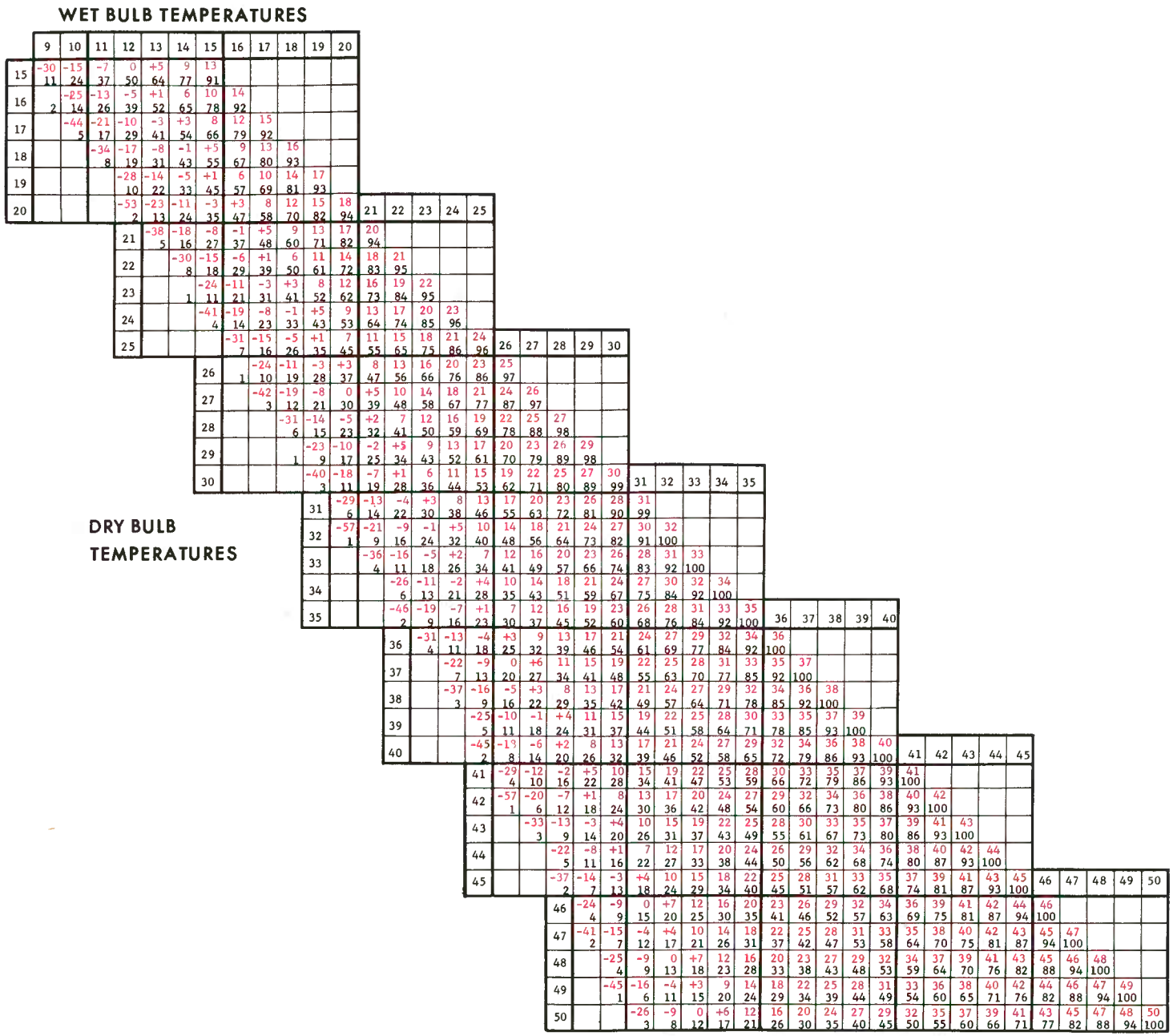
WET BULB TEMPERATURES
DRY BULB TEMPERATURES

WET BULB TEMPERATURES

DRY BULB TEMPERATURES	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
81	-23 1	-5 3	+5 5	12 7	17 9	22 11	26 13	30 16	33 18	36 20	39 22	42 25	44 27	46 30	48 32	50 35	52 37	54 40	56 43	58 45	60 48	61 51	63 54	64 57	66 60	68 64	69 67	70 70	72 74	73 77	75 81	76 84	77 88	78 92	80 96	81 100					
82	-40 1	-11 2	+1 4	9 6	15 8	20 10	25 12	29 14	32 16	35 19	38 21	41 23	43 25	46 28	48 30	50 33	52 35	54 38	56 41	57 43	59 46	61 49	62 52	64 55	66 58	67 61	69 64	70 67	71 71	73 74	74 77	76 81	77 85	78 88	79 92	81 96	82 100				
83		-19 2	-3 3	+6 5	13 7	19 9	23 11	27 13	31 15	34 17	37 19	40 22	42 24	45 26	47 29	49 31	51 33	53 36	55 38	57 41	59 44	60 47	62 49	64 52	65 55	67 58	68 61	70 64	71 68	73 71	74 74	75 78	77 81	78 85	79 88	80 92	82 96	83 100			
84		-31 1	-8 3	+3 4	11 6	17 8	22 10	26 12	30 14	33 16	36 18	39 20	42 22	44 25	46 27	49 29	51 32	53 34	55 37	56 39	58 42	60 44	62 47	63 50	65 53	66 56	68 59	69 62	71 65	72 68	74 71	75 74	76 78	78 81	79 85	80 89	82 92	83 96	84 100		
85			-15 2	-1 4	+8 5	14 7	20 9	24 11	28 13	32 15	35 17	38 19	41 21	43 23	46 25	48 28	50 30	52 32	54 35	56 37	58 40	59 42	61 45	63 48	64 50	66 53	68 56	69 59	70 62	72 65	73 68	75 71	76 75	77 78	79 81	80 85	81 89	83 92	84 96	85 100
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93						-18 1	-2 3	+8 4	15 6	20 7	25 9	29 10	33 12	36 14	39 15	42 17	44 19	47 21	49 23	51 24	53 26	55 28	57 30	59 33	61 35	63 37	64 39	66 41	68 44	69 46	71 49	72 51	74 54	75 56	76 59	78 62	79 64	81 67	82 70	83 73	
94						-31 1	-7 2	+4 3	12 5	18 6	23 8	28 9	32 11	35 13	38 14	41 16	44 18	46 20	49 21	51 23	53 25	55 27	57 29	59 31	61 33	62 35	64 37	66 40	67 42	69 44	70 47	72 49	73 51	75 54	76 57	78 59	79 62	80 65	82 68	83 71	
95							-13 1	+1 3	10 4	16 6	22 7	26 9	30 10	34 12	37 13	40 15	43 17	45 18	48 20	50 22	52 24	54 26	56 28	58 30	60 32	62 34	64 36	65 38	67 40	69 42	70 45	72 47	73 49	75 52	76 54	77 57	79 60	80 62	81 65	83 68	
96						-22 1	-3 2	+7 4	14 5	20 6	25 8	29 9	33 11	36 12	39 14	42 16	45 17	47 19	50 21	52 23	54 24	56 26	58 28	60 30	61 32	63 34	65 36	67 38	68 41	70 43	71 45	73 47	74 50	76 52	77 55	78 57	80 60	81 63	82 65	
97						-38	-9 2	+4 3	12 4	18 6	23 7	28 9	32 10	35 12	38 13	41 15	44 16	46 18	49 20	51 21	53 23	55 25	57 27	59 29	61 31	63 33	64 35	66 37	68 39	69 41	71 43	72 45	74 48	75 50	77 53	78 55	80 58	81 60	82 63	
98							-16 1	0 2	+9 4	16 5	22 6	26 8	30 9	34 11	37 12	40 14	43 15	46 17	48 19	50 20	53 22	55 24	57 26	59 27	61 29	62 31	64 33	66 35	67 37	69 39	71 41	72 43	74 46	75 48	76 51	78 53	79 55	81 58	82 60	
99							-26 1	-5 2	+6 3	14 4	20 6	25 7	29 9	33 10	36 11	39 13	42 14	45 16	48 18	50 19	52 21	54 23	56 24	58 26	60 28	62 30	64 32	65 34	67 36	69 38	70 40	72 42	73 44	75 46	76 49	78 51	79 53	80 56	82 58	
100							-47	-10 1	+3 3	11 4	18 5	23 7	28 8	32 9	35 11	39 12	42 14	44 15	47 17	49 18	51 20	54 21	56 23	58 25	60 27	61 28	63 30	65 32	67 34	68 36	70 38	71 40	73 42	74 44	76 47	77 49	79 51	80 54	81 56	
101								-18 1	-1 2	+9 3	16 5	22 6	26 7	31 9	34 10	38 11	41 13	43 14	46 16	49 17	51 19	53 20	55 22	57 24	59 25	61 27	63 29	65 31	66 33	68 35	70 37	71 39	73 41	74 43	76 45	77 47	78 49	80 52	81 54	
102							-29	-6 2	+6 3	14 4	20 5	25 7	29 8	33 9	37 11	40 12	43 13	45 15	48 16	50 18	53 19	55 21	57 23	59 24	61 26	62 28	64 29	66 31	68 33	69 35	71 37	72 39	74 41	75 43	77 45	78 47	80 50	81 52	
103								-12 1	+2 2	11 4	18 5	23 6	28 7	32 9	36 10	39 11	42 13	45 14	47 15	50 17	52 18	54 20	56 22	58 23	60 25	62 26	64 28	66 30	67 32	69 34	70 35	72 37	74 39	75 41	76 43	78 46	79 48	81 50	
104								-20 1	-2 2	+9 3	16 4	22 5	27 7	31 8	35 9	38 10	41 12	44 13	46 15	49 16	51 17	54 19	56 20	58 22	60 24	62 25	63 27	65 29	67 30	68 32	70 34	72 36	73 38	75 40	76 42	78 44	79 46	80 48	
105								-33	-6 1	+6 3	14 4	20 5	25 6	30 7	33 9	37 10	40 11	43 12	46 14	48 15	51 17	53 18	55 20	57 21	59 23	61 24	63 26	65 27	66 29	68 31	70 33	71 34	73 36	74 38	76 40	77 42	79 44	80 46	
106									-13 1	+2 2	11 3	18 4	24 6	28 7	32 8	36 9	39 10	42 12	45 13	48 14	50 16	52 17	55 19	57 20	59 22	61 23	63 25	64 26	66 28	68 30	69 31	71 33	73 35	74 37	76 39	77 41	79 43	80 45	
107									-21 1	-2 2	+9 3	16 4	22 5	27 6	31 7	35 9	38 10	41 11	44 12	47 14	49 15	52 16	54 18	56 19	58 21	60 22	62 24	64 25	66 27	67 28	69 30	71 32	72 34	74 35	75 37	77 39	78 41	80 43	
108									-35	-7 1	+5 2	14 3	20 5	25 6	30 7	34 8	37 9	41 10	43 12	46 13	49 14	51 15	53 17	56 18	58 20	60 21	62 23	63 24	65 26	67 27	69 29	70 31	72 32	74 34	75 36	77 38	78 39	79 41	
109										-13 1	+2 2	11 3	18 4	24 5	29 6	33 7	36 9	40 10	43 11	45 12	48 13	51 15	53 16	55 17	57 19	59 20	61 22	63 23	65 25	67 26	68 28	70 29	72 31	73 33	75 34	76 36	78 38	79 40	

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
51	-48 1	-16 5	-5 10	+3 14	9 18	14 23	18 27	22 32	25 36	28 41	31 46	33 51	36 56	38 61	40 66	42 72	44 77	46 83	48 88	49 94	51 100				
52		-27 3	-10 7	-1 11	+6 15	12 20	16 24	20 28	24 33	27 37	30 42	32 47	35 52	37 57	39 62	41 67	43 72	45 77	47 83	49 88	50 94	52 100			
53		-50 1	-18 5	-5 9	+3 13	9 17	14 21	18 25	22 30	25 34	28 38	31 43	34 48	36 52	38 57	40 62	42 67	44 73	46 78	48 83	50 89	51 94	53 100		
54			-29 2	-11 6	-1 10	+6 14	12 18	16 22	20 26	24 31	27 35	30 39	33 44	35 49	37 53	40 58	42 63	44 68	46 73	47 78	49 83	51 89	52 94	54 100	
55			-57	-19 4	-6 8	+3 12	9 16	14 20	18 24	22 28	26 32	29 36	31 40	34 45	36 49	39 54	41 59	43 64	45 68	47 73	48 79	50 84	52 89	53 94	55 100
56			-30 2	-11 6	-1 9	+6 13	12 17	16 21	21 25	24 29	27 33	30 37	33 41	35 46	38 50	40 55	42 59	44 64	46 69	48 74	50 79	51 84	53 89	54 95	56 100
57				-19 4	-6 7	+3 11	9 15	14 18	19 22	22 26	26 30	29 34	32 38	34 42	37 47	39 51	41 55	43 60	45 65	47 69	49 74	51 79	52 84	54 89	55 95	57 100
58				-32 2	-12 5	-1 9	+6 12	12 16	17 20	21 23	24 27	28 31	31 35	33 39	36 43	38 47	40 52	42 56	44 61	46 65	48 70	50 75	52 79	53 84	55 90	56 95	58 100
59					-20 3	-6 7	+3 10	9 14	15 17	19 21	23 25	26 28	29 32	32 36	35 40	37 44	39 48	42 52	44 57	46 61	48 66	49 70	51 75	53 80	54 85	56 90	58 95	59 100
60					-32 2	-12 5	-1 8	+6 12	12 15	17 18	21 22	25 26	28 29	31 33	34 37	36 41	39 45	41 49	43 53	45 57	47 62	49 66	50 71	52 75	54 80	55 85	57 90	59 95	60 100
61						-20 3	-6 6	+3 10	10 13	15 16	19 20	23 23	27 27	30 30	33 34	35 38	38 42	40 46	42 50	44 54	46 58	48 62	50 67	52 71	53 76	55 80	56 85	58 90	60 95	61 100
62						-32 2	-11 5	-1 8	+7 11	13 14	17 17	21 21	25 24	28 28	31 31	34 35	37 39	39 43	41 46	43 50	45 54	47 59	49 63	51 67	53 72	54 76	56 81	58 85	59 90	61 95	62 100
63							-19 3	-5 6	+4 9	10 12	15 15	20 19	24 22	27 25	30 29	33 32	36 36	38 40	40 43	43 47	45 51	47 55	49 59	50 63	52 68	54 72	55 76	57 81	59 85	60 90	62 95	63 100
64							-32 1	-11 4	0 7	+7 10	13 13	18 17	22 20	26 23	29 26	32 30	35 33	37 37	40 40	42 44	44 48	46 52	48 56	50 60	52 64	53 68	55 72	57 77	58 81	60 86	61 90	63 95	64 100
65								-19 3	-5 6	+4 9	11 12	16 15	20 18	24 21	28 24	31 27	34 31	36 34	39 38	41 41	43 45	45 49	47 52	49 56	51 60	53 64	54 68	56 73	58 77	59 81	61 86	62 90	64 95	65 100
66									-31 1	-10 4	0 7	+8 10	14 13	18 16	22 19	26 22	29 25	32 28	35 32	38 35	40 39	42 42	44 46	46 49	48 53	50 57	52 61	54 65	55 69	57 73	59 77	60 82	62 86	63 91	65 95	66 100
67										-18 3	-4 6	+5 8	11 11	16 14	21 17	25 20	28 23	31 26	34 29	37 33	39 36	41 39	44 43	46 46	48 50	50 54	51 57	53 61	55 65	57 69	58 73	60 78	61 82	63 86	64 91	66 95	67 100
68										-29 1	-9 4	+1 7	8 10	14 12	19 15	23 18	27 21	30 24	33 27	36 30	38 33	41 37	43 40	45 44	47 47	49 51	51 54	53 58	54 62	56 66	58 70	59 74	61 78	62 82	64 86	65 91	67 95	68 100
69										-58	-16 3	-3 5	+5 8	12 11	17 13	21 16	25 19	29 22	32 25	35 28	37 31	40 34	42 38	44 41	46 44	48 48	50 51	52 55	54 58	56 62	57 66	59 70	60 74	62 78	63 82	65 87	66 91	68 95	69 100
70											-27 2	-8 4	+2 7	9 9	15 12	20 15	24 17	27 20	31 23	34 26	36 29	39 32	41 35	43 38	46 42	48 45	50 48	51 52	53 55	55 59	57 63	58 66	60 70	61 74	63 78	64 82	66 87	67 91	69 95	70 100
71												-50	-15 3	-2 5	+6 8	13 10	18 13	22 16	26 18	29 21	32 24	35 27	38 30	40 33	43 36	45 39	47 42	49 46	51 49	53 52	54 56	56 59	58 63	59 67	61 71	63 75	64 79	65 83	67 87	68 91	70 96	71 100
72													-25 2	-7 4	+3 6	10 9	16 11	20 14	24 17	28 19	31 22	34 25	37 28	39 31	42 34	44 37	46 40	48 43	50 46	52 50	54 53	56 56	57 60	59 64	61 67	62 71	64 75	65 79	67 83	68 87	69 91	71 96	72 100
73													-43 1	-13 3	-1 5	+7 8	13 10	18 13	23 15	27 18	30 20	33 23	36 26	39 29	41 32	43 34	46 37	48 41	50 44	52 47	53 50	55 53	56 57	58 60	60 64	62 68	63 71	65 75	66 79	68 83	69 87	70 91	72 96	73 100
74														-22 2	-6 4	+4 6	11 9	16 11	21 14	25 16	29 19	32 21	35 24	38 27	40 29	43 32	45 35	47 38	49 41	51 44	53 47	55 51	56 54	58 57	60 61	61 64	63 68	64 72	66 75	67 79	69 83	70 87	71 91	73 96	74 100
75														-37 1	-12 3	0 5	+8 7	14 10	19 12	24 15	27 17	31 20	34 22	37 25	39 28	42 30	44 33	46 36	48 39	50 42	52 45	54 48	56 51	58 55	59 58	61 61	62 65	64 68	65 72	67 76	68 80	70 83	71 87	72 92	74 96	75 100
76															-19 2	-4 4	+5 6	12 9	17 11	22 13	26 16	30 18	33 21	36 23	38 26	41 28	43 31	45 34	48 37	50 40	52 43	53 46	55 49	57 52	59 55	60 58	62 62	63 65	65 69	66 72	68 76	69 80	71 84	72 88	73 92	75 96	76 100
77															-32 1	-10 3	+2 5	9 7	15 10	20 12	24 14	28 17	32 19	35 21	37 24	40 26	42 29	45 32	47 35	49 37	51 40	53 43	55 46	56 49	58 52	60 55	61 59	63 62	65 66	66 69	68 73	69 76	70 80	72 84	73 88	74 92	76 96	77 100
78																-17 2	-3 4	+6 6	13 8	18 11	23 13	27 15	30 17	33 20	36 22	39 25	42 27	44 30	46 33	48 35	50 38	52 41	54 44	56 47	58 50	59 53	61 56	63 59	64 63	66 66	67 69	69 73	70 76	71 80	73 84	74 88	75 92	77 96	78 100
79																-27 1	-8 3	+3 5	11 7	16 9	21 12	25 14	29 16	32 18	35 21	38 23	41 26	43 28	45 31	48 33	50 36	52 39	54 41	55 44	57 47	59 50	61 53	62 56	64 60	65 63	67 66	68 70	70 73	71 77	72 80	74 84	75 88	76 92	78 96	79 100
80																-52	-14 2	-1 4	+8 6	14 8	19 10	24 12	28 15	31 17	34 19	37 22	40 24	42 26	45 29	47 31	49 34	51 37	53 39	55 42	57 45	58 48	60 51	62 54	63 57	65 60	66 63	68 67	69 70	71 73	72 77	73 81	75 84	76 88	77 92	79 96	80 100

WS TA B-0-5B
(11-73)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RELATIVE HUMIDITY and DEW POINT TABLE

Pressure 25 Inches of Mercury

For use at elevations between 3,901 and 6,100 feet above sea level
(In Alaska use at elevations between 3,601 and 5,700 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

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WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
20	-31 9	-14 20	-5 32	+2 44	7 56	11 68	15 81	18 94																																			
21		-25 11	-11 23	-3 34	+3 46	8 58	13 70	16 82	20 94																																		
22		-46 3	-20 14	-8 25	-1 36	+5 48	10 59	14 71	18 83	21 95																																	
23			-34 6	-16 17	-6 27	+1 38	7 49	11 61	15 72	19 83	22 95																																
24				-27 9	-12 19	-3 30	+3 40	9 51	13 62	17 73	20 84	23 96																															
25				-52 2	-21 12	-9 22	-1 32	+5 42	10 53	14 63	18 74	21 85	24 96																														
26					-36 5	-16 14	-6 24	+1 34	7 44	12 54	16 65	19 75	22 86	25 97																														
27						-27 8	-12 17	-3 26	+4 36	9 46	13 56	17 66	21 76	24 87	26 97																												
28						-56 1	-21 10	-9 19	0 29	+6 38	11 48	15 57	19 67	22 77	25 87	27 98																											
29							-37 4	-16 13	-5 22	+2 31	8 40	12 49	16 59	20 68	23 78	26 88	29 98																										
30								-27 7	-11 15	-2 24	+4 33	10 42	14 51	18 60	21 70	24 79	27 89	30 99																									
31									-54 1	-20 10	-8 18	0 26	+6 35	11 44	16 52	19 61	23 71	26 80	28 90	31 99																									
32										-35 4	-15 12	-4 20	+3 28	9 37	13 45	17 54	21 63	24 72	27 81	30 90	32 100																								
33											-25 7	-10 15	-1 22	+5 30	11 39	15 47	19 56	22 64	25 73	28 82	31 91	33 100																						
34											-48 2	-18 9	-6 17	+2 25	8 32	12 40	17 49	20 57	24 65	27 74	29 83	32 91	34 100																				
35												-31 4	-13 12	-3 19	+4 27	10 34	14 42	18 50	22 58	25 67	28 75	30 83	33 92	35 100																				
36													-22 7	-9 14	0 21	+7 29	12 36	16 44	20 52	23 60	26 68	29 76	32 84	34 92	36 100																			
37													-40 3	-16 9	-5 16	+3 23	9 31	14 38	18 46	22 53	25 61	28 69	30 76	33 84	35 92	37 100																		
38														-27 5	-11 12	-1 19	+6 26	11 33	16 40	20 47	23 55	26 62	29 69	31 77	34 84	36 92	38 100																	
39														-55 1	-19 7	-6 14	+2 21	8 27	13 34	18 42	21 49	25 56	27 63	30 70	33 77	35 85	37 92	39 100																
40															-32 3	-13 10	-2 16	+5 23	11 29	15 36	19 43	23 50	26 57	29 64	31 71	34 78	36 85	38 92	40 100															
41																-22 6	-8 12	+1 18	8 25	13 31	17 38	21 44	24 51	27 58	30 64	32 71	35 78	37 85	39 93	41 100												
42																-39 2	-15 8	-2 14	+4 20	10 27	15 33	19 39	23 46	26 52	29 58	31 65	34 72	36 79	38 86	40 93	42 100										
43																	-25 5	-9 10	0 16	+7 22	13 29	17 35	21 41	24 47	27 53	30 59	32 66	35 72	37 79	39 86	41 93	43 100									
44																	-48 1	-17 7	-4 13	+4 18	10 24	15 30	19 36	22 42	25 48	28 54	31 60	34 66	36 73	38 80	40 86	42 93	44 100								
45																		-29 4	-10 9	0 15	+7 20	12 26	17 31	20 37	24 43	27 49	30 55	32 61	35 67	37 73	39 80	41 86	43 93	45 100							
46																			-19 6	-5 11	+3 17	9 22	14 27	18 33	22 38	25 44	28 50	31 56	34 62	36 68	38 74	40 80	42 87	44 93	46 100					
47																			-32 3	-12 8	-1 13	+6 18	12 23	16 29	20 34	24 40	27 45	30 51	32 57	35 62	37 68	39 74	41 81	43 87	45 93	47 100				
48																				-20 5	-6 10	+2 15	9 20	14 25	18 30	22 35	25 41	28 46	31 52	34 57	36 63	38 69	40 75	42 81	44 87	46 94	48 100			
49																				-35 2	-13 7	-2 12	+5 17	11 21	16 26	20 31	24 37	27 42	30 47	32 53	35 58	37 64	39 70	42 75	44 81	45 87	47 94	49 100		
50																					-22 4	-7 9	+2 13	8 18	14 23	18 28	22 33	25 38	28 43	31 48	34 53	36 59	39 64	41 70	43 76	45 82	46 88	48 94	50 100		
51																						-39 2	-14 6	-3 10	+5 15	11 20	16 24	20 29	24 34	27 39	30 44	33 49	35 54	37 60	40 65	42 71	44 76	46 82	48 88	49 94	51 100	
52																							-24 3	-8 8	+1 12	8 17	13 21	18 26	22 30	25 35	28 40	31 45	34 50	36 55	39 60	41 66	43 71	45 77	47 82	49 88	50 94	52 100	
53																							-45 1	-16 5	-3 9	+5 14	11 18	16 22	20 27	24 32	27 36	30 41	33 46	35 51	38 56	40 61	42 66	44 72	46 77	48 83	50 88	51 94	53 100
54																								-27 3	-9 7	+1 11	8 15	13 19	18 24	22 28	25 33	29 37	31 42	34 47	37 52	39 57	41 62	43 67	45 72	47 77	49 83	51 89	52 94	54 100
55																								-53 1	-17 5	-4 8	+4 13	11 17	16 21	20 25	24 29	27 34	30 38	33 43	36 48	38 52	40 57	42 62	44 67	46 73	48 78	50 83	52 89	53 94	55 100

WET BULB TEMPERATURES

DRY BULB TEMPERATURES	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
56	-29	-10	0	+8	13	18	22	26	29	32	34	37	39	41	44	46	47	49	51	53	54	56				
	2	6	10	14	18	22	26	31	35	39	44	49	53	58	63	68	73	78	83	89	94	100				
57		-18	-4	+4	11	16	20	24	27	30	33	36	38	41	43	45	47	49	50	52	54	55	57			
		4	8	12	15	19	23	28	32	36	40	45	49	54	59	64	68	73	79	84	89	94	100			
58		-31	-10	0	+7	13	18	22	26	29	32	35	37	40	42	44	46	48	50	51	53	55	56	58		
		2	6	9	13	17	21	25	29	33	37	41	46	50	55	59	64	69	74	79	84	89	95	100		
59			-19	-5	+4	11	16	20	24	28	31	34	36	39	41	43	45	47	49	51	53	54	56	57	59	
			4	7	11	14	18	22	26	30	34	38	42	47	51	55	60	65	69	74	79	84	89	95	100	
60			-32	-11	0	+8	13	18	22	26	29	32	35	38	40	42	44	46	48	50	52	54	55	57	58	60
			2	5	9	12	16	19	23	27	31	35	39	43	47	52	56	61	65	70	75	79	84	90	95	100
61			-19	-5	+4	11	16	21	24	28	31	34	37	39	41	43	46	48	49	51	53	55	56	58	59	61
			3	7	10	14	17	21	24	28	32	36	40	44	48	52	57	61	66	70	75	80	85	90	95	100
62			-33	-11	0	+8	14	19	23	26	30	33	35	38	40	43	45	47	49	51	52	54	56	57	59	61	62
			1	5	8	11	15	18	22	26	29	33	37	41	45	49	53	57	62	66	71	75	80	85	90	95	100
63				-19	-5	+4	11	16	21	25	28	31	34	37	39	42	44	46	48	50	52	54	55	57	58	60	62	63
				3	6	9	13	16	20	23	27	30	34	38	42	46	50	54	58	62	67	71	76	80	85	90	95	100
64				-34	-11	0	+8	14	19	23	27	30	33	36	38	41	43	45	47	49	51	53	55	56	58	60	61	63	64
				1	4	8	11	14	17	21	24	28	31	35	39	43	46	50	54	59	63	67	72	76	81	85	90	95	100
65					-19	-4	+5	11	17	21	25	29	32	35	37	40	42	44	47	49	50	52	54	56	57	59	61	62	64	65
					3	6	9	12	15	19	22	25	29	32	36	40	43	47	51	55	59	63	68	72	76	81	86	90	95	100
66				-33	-10	+1	8	14	19	23	27	31	34	36	39	41	44	46	48	50	52	53	55	57	58	60	62	63	65	66
				1	4	7	10	13	16	20	23	26	30	33	37	40	44	48	52	56	60	64	68	72	77	81	86	90	95	100
67					-19	-4	+5	12	17	22	26	29	32	35	38	40	43	45	47	49	51	53	55	56	58	60	61	63	64	66	67
					3	6	8	11	15	18	21	24	27	31	34	38	41	45	49	52	56	60	64	68	73	77	81	86	90	95	100
68					-32	-10	+1	9	15	20	24	28	31	34	37	39	42	44	46	48	50	52	54	56	57	59	61	62	64	65	67	68
					1	4	7	10	13	16	19	22	25	28	32	35	39	42	46	49	53	57	61	65	69	73	77	82	86	91	95	100
69						-18	-3	+6	12	18	22	26	30	33	36	38	41	43	45	48	50	52	53	55	57	59	60	62	63	65	66	68	69
						3	5	8	11	14	17	20	23	26	29	33	36	39	43	46	50	54	57	61	65	69	73	78	82	86	91	95	100
70						-31	-9	+2	10	15	20	25	28	32	35	37	40	42	45	47	49	51	53	55	56	58	60	61	63	64	66	67	69	70
						1	4	7	9	12	15	18	21	24	27	30	33	37	40	44	47	51	54	58	62	66	70	74	78	82	86	91	95	100
71							-17	-3	+6	13	18	23	27	30	33	36	39	41	44	46	48	50	52	54	56	57	59	61	62	64	65	67	68	70	71
							3	5	8	11	13	16	19	22	25	28	31	34	38	41	44	48	51	55	58	62	66	70	74	78	82	87	91	95	100
72							-29	-8	+3	10	16	21	25	29	32	35	38	41	43	45	47	49	51	53	55	57	59	60	62	63	65	66	68	69	71	72
							1	4	6	9	12	14	17	20	23	26	29	32	35	38	42	45	48	52	55	59	63	66	70	74	78	83	87	91	95	100
73								-15	-2	+7	14	19	23	27	31	34	37	40	42	44	47	49	51	53	55	56	58	60	61	63	64	66	67	69	70	72	73
								3	5	8	10	13	16	18	21	24	27	30	33	36	39	42	46	49	52	56	59	63	67	71	75	79	83	87	91	96	100
74								-26	-7	+4	11	17	22	26	30	33	36	39	41	44	46	48	50	52	54	56	58	59	61	62	64	66	67	68	70	71	73	74
								1	4	6	9	11	14	17	19	22	25	28	31	34	37	40	43	46	50	53	56	60	64	67	71	75	79	83	87	91	96	100
75								-52	-14	0	+8	15	20	24	28	32	35	38	40	43	45	47	49	51	53	55	57	59	60	62	64	65	67	68	70	71	72	74	75
									3	5	7	10	12	15	18	20	23	26	29	31	34	37	41	44	47	50	53	57	60	64	68	71	75	79	83	87	91	96	100
76									-24	-5	+5	12	18	22	27	30	33	36	39	42	44	47	49	51	53	55	56	58	60	62	63	65	66	68	69	71	72	73	75	76
									2	4	6	9	11	13	16	19	21	24	27	29	32	35	38	41	44	47	51	54	57	61	64	68	72	75	79	83	87	91	96	100
77									-43	-12	+1	9	15	21	25	29	32	35	38	41	43	46	48	50	52	54	56	58	59	61	63	64	66	67	69	70	72	73	74	76	77
										3	5	7	10	12	14	17	19	22	25	27	30	33	36	39	42	45	48	51	55	58	61	65	68	72	76	80	83	87	92	96	100
78										-21	-4	+6	13	19	23	27	31	34	37	40	43	45	47	49	51	53	55	57	59	61	62	64	65	67	68	70	71	73	74	75	77	78
										2	4	6	8	11	13	15	18	20	23	26	28	31	34	37	40	42	46	49	52	55	58	62	65	69	72	76	80	84	88	92	96	100
79										-36	-10	+2	10	16	21	26	30	33	36	39	42	44	46	49	51	53	55	57	58	60	62	63	65	66	68	69	71	72	74	75	76	78	79
										1	3	5	7	9	12	14	16	19	21	24	26	29	32	35	37	40	43	46	49	52	56	59	62	66	69	73	76	80	84	88	92	96	100
80											-18	-2	+7	14	20	24	28	32	35	38	41	43	46	48	50	52	54	56	58	60	61	63	65	66	68	69	71	72	73	75	76	77	79	80
											2	4	6	8	10	13	15	17	20	22	25	27	30	32	35	38	41	44	47	50	53	56	59	63	66	69	73	77	80	84	88	92	96	100
81												-31	-8	+4	11	17	22	27	30	34	37	40	42	45	47	49	51	53	55	57	59	61	62	64	66	67	69	70	72	73	74	76	77	78	80	81
												1	3	5	7	9	11	14	16	18	21	23	25	28	31	33	36	39	41	44	47	50	53	56	60	63	66	70	73	77	80	84	88	92	96	100
82												-57	-15	-1	+8	15	21	25	29	33	36	39	41	44	46	49	51	53	55	57	59	60	62	64	65	67	68	70	71	73	74	75	77	78	80	81	82
													2	4	6	8	10	12	15	17	19	21	24	26	29	31	34	37	39	42	45	48	51	54	57	60	63	67	70	73	77	81	84	88	92	96	100
83													-26	-6	+5	13	19	23	28	31	35	38	41	43	46	48	50	52	54	56	58	60	61	63	65	66	68	69	71	72	74	75	76	78	79	80	82	83
													1	3	5	7	9	11	13	15	18	20	22	25	27	29	32	35	37	40	43	45	48	51	54	57	60	64	67	70	74	77	81	84	88	92	96	100
84														-49	-12	+1	10	16	22	26	30	34	37	40	42	45	47	49	52	54	56	57	59	61	63	64	66	68	69	71	72	73	75	76	78	79	80	81	83	84
															2	4	6	8	10	12	14	16	18	21	23	25	28	30	33	35	38	41	43	46	49	52	55	58	61	64	67	71	74	77	81	85	88	92	96	100
85															-21	-3	+7	14	20	24	29	32	36	39	41	44	46	49	51	53	55	57	59	61	62	64	66	67	69	70	72	73	74	76	77	79	80	81	82	84	85
															1	3	5	7	9	11	13	15	17	19	22	24	26	28	31	33	36	38	41	44	47	49	52	55	58	61	64	68	71	74	78	81	85	88	92	96	100

WET BULB TEMPERATURES

DRY BULB TEMPERATURES	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
86	-37 1	-9 2	+3 4	11 6	18 8	23 10	27 12	31 14	34 16	38 18	40 20	43 22	46 25	48 27	50 29	52 32	54 34	56 36	58 39	60 42	62 44	63 47	65 50	67 53	68 56	70 59	71 62	73 65	74 68	76 71	77 74	78 78	80 81	81 85	82 89	83 92	85 96	86 100				
87		-17 2	-1 3	+8 5	15 7	21 9	26 11	30 13	33 15	36 17	39 19	42 21	45 23	47 25	50 28	52 30	54 32	56 35	58 37	60 40	61 42	63 45	65 48	66 50	68 53	69 56	71 59	72 62	74 65	75 68	77 71	78 75	79 78	81 82	82 85	83 89	85 92	86 96	87 100			
88		-29 1	-6 2	+5 4	13 6	19 8	24 10	28 12	32 13	35 15	38 17	41 20	44 22	46 24	49 26	51 28	53 31	55 33	57 35	59 38	61 40	63 43	64 45	66 48	67 51	69 54	71 56	72 59	73 62	75 65	76 68	78 72	79 75	80 78	82 82	83 85	84 89	86 92	87 96	88 100		
89			-13 2	+1 3	10 5	17 7	22 9	27 11	31 12	34 14	37 16	40 18	43 20	46 22	48 24	50 27	53 29	55 31	57 33	58 36	60 38	62 41	64 43	65 46	67 49	69 51	70 54	72 57	73 60	75 63	76 66	77 69	79 72	80 75	81 78	82 82	84 85	85 89	87 93	88 96	89 100		
90			-22 1	-3 3	+7 4	14 6	20 8	25 10	29 11	33 13	36 15	39 17	42 19	45 21	47 23	50 25	52 27	54 30	56 32	58 34	60 36	62 39	63 41	65 44	67 46	68 49	70 52	71 54	73 57	74 60	76 63	77 66	78 69	80 72	81 75	82 79	84 82	85 85	86 89	88 93	89 96	90 100	
91	-40	-9 2	+3 4	12 5	18 7	23 9	28 10	32 12	35 14	38 16	41 18	44 20	47 22	49 24	51 26	53 28	55 30	57 32	59 35	61 37	63 39	65 42	66 44	68 47	69 49	71 52	72 55	74 58	75 60	77 63	78 66	80 69	81 72	82 76	84 79	85 82	86 86	87 89	89 93	90 96		
92		-17 1	-1 3	+9 4	16 6	22 8	26 9	30 11	34 13	37 15	40 17	43 19	46 20	48 22	51 24	53 27	55 29	57 31	59 33	61 35	62 38	64 40	66 42	67 45	69 47	71 50	72 52	74 55	75 58	76 61	78 64	79 67	81 70	82 73	83 76	85 79	86 82	87 86	88 89	90 93		
93		-29 1	-6 2	+6 4	14 5	20 7	25 9	29 10	33 12	36 14	39 16	42 17	45 19	48 21	50 23	52 25	54 27	56 29	58 31	60 34	62 36	64 38	65 40	67 43	69 45	70 48	72 50	73 53	75 56	76 58	78 61	79 64	80 67	82 70	83 73	84 76	86 79	87 82	88 86	89 89		
94			-12 2	+2 3	11 5	18 6	23 8	28 9	32 11	35 13	38 14	41 16	44 18	47 20	49 22	51 24	54 26	56 28	58 30	60 32	61 34	63 36	65 39	67 41	68 43	70 46	71 48	73 51	74 53	76 56	77 59	79 61	80 64	81 67	83 70	84 73	85 76	87 79	88 83	89 86		
95			-22 1	-3 2	+8 4	15 5	21 7	26 9	30 10	34 12	37 13	40 15	43 17	46 19	48 21	51 22	53 24	55 26	57 28	59 30	61 33	63 35	65 37	66 39	68 41	69 44	71 46	73 49	74 51	76 54	77 56	78 59	80 62	81 65	82 67	84 70	85 73	86 76	88 80	89 83		
96	-39	-8 2	+4 3	13 5	19 6	24 8	29 9	33 11	36 13	40 14	42 16	45 18	48 19	50 21	52 23	55 25	57 27	59 29	60 31	62 33	64 35	66 37	67 40	69 42	71 44	72 47	74 49	75 51	77 54	78 57	80 59	81 62	82 65	84 68	85 71	86 74	87 77	89 80			
97		-16 1	0 3	+10 4	17 5	23 7	27 8	32 10	35 12	39 13	42 15	44 17	47 18	49 20	52 22	54 24	56 26	58 28	60 30	62 32	64 34	65 36	67 38	69 40	70 42	72 45	73 47	75 49	76 52	78 54	79 57	81 60	82 62	83 65	85 68	86 71	87 74	88 77				
98		-27 1	-4 2	+7 3	15 5	21 6	26 8	30 9	34 11	37 12	41 14	44 16	46 17	49 19	51 21	53 23	55 24	58 26	59 28	61 30	63 32	65 34	67 36	68 38	70 41	72 43	73 45	75 47	76 50	78 52	79 55	80 57	82 60	83 63	84 65	86 68	87 71	88 74				
99		-54	-10 1	+3 3	12 4	19 6	24 7	29 8	33 10	36 11	40 13	43 15	45 16	48 18	50 20	53 21	55 23	57 25	59 27	61 29	63 31	65 33	66 35	68 37	70 39	71 41	73 43	74 46	76 48	77 50	79 53	80 55	81 58	83 60	84 63	85 66	87 68	88 71				
100			-19 1	-1 2	+9 4	17 5	22 6	27 8	32 9	35 11	39 12	42 14	45 15	47 17	50 19	52 20	54 22	56 24	58 26	60 27	62 29	64 31	66 33	68 35	69 37	71 39	72 41	74 44	75 46	77 48	78 51	80 53	81 55	83 58	84 61	85 63	87 66	88 69				
101	-33	-6 2	+6 3	14 4	21 6	26 7	30 8	34 10	38 11	41 13	44 14	46 16	49 18	51 19	54 21	56 23	58 24	60 26	62 28	64 30	65 32	67 34	69 36	70 38	72 40	74 42	75 44	77 46	78 49	79 51	81 53	82 56	84 58	85 61	86 63	88 66						
102		-13 1	+2 2	12 4	19 5	24 6	29 8	33 9	37 11	40 12	43 13	46 15	48 17	51 18	53 20	55 21	57 23	59 25	61 27	63 28	65 30	67 32	68 34	70 36	72 38	73 40	75 42	76 44	78 47	79 49	81 51	82 54	83 56	85 59	86 61	87 64						
103		-22 1	-2 2	+9 3	16 4	22 6	27 7	32 8	35 10	39 11	42 13	45 14	48 16	50 17	52 19	55 20	57 22	59 24	61 25	63 27	65 29	66 31	68 33	70 35	71 37	73 39	74 41	76 43	77 45	79 47	80 49	82 52	83 54	84 56	86 59	87 61						
104		-39	-7 1	+5 3	14 4	20 5	26 6	30 8	34 9	38 10	41 12	44 13	47 15	49 16	52 18	54 19	56 21	58 23	60 24	62 26	64 28	66 29	68 31	69 33	71 35	73 37	74 39	76 41	77 43	79 45	80 47	81 50	82 52	84 54	86 57	87 59						
105			-14 1	+2 2	11 3	18 5	24 6	29 7	33 8	37 10	40 11	43 12	46 14	49 15	51 17	53 18	56 20	58 21	60 23	62 25	64 26	65 28	67 30	69 32	71 34	72 36	74 37	75 39	77 41	78 44	80 46	81 48	83 50	84 52	85 55	87 57							
106	-25 1	-3 2	+8 3	16 4	22 5	27 6	32 8	36 9	39 10	42 12	45 13	48 14	50 16	53 17	55 19	57 20	59 22	61 24	63 25	65 27	67 29	69 30	70 32	72 34	73 36	75 38	77 40	78 42	80 44	81 46	82 48	84 50	85 53	86 55								
107	-47	-8 1	+5 2	14 4	20 5	26 6	30 7	35 8	38 10	41 11	44 12	47 14	50 15	52 17	54 18	57 19	59 21	61 23	63 24	65 26	66 27	68 29	70 31	72 33	73 35	75 36	76 38	78 40	79 42	81 44	82 46	83 49	85 51	86 53								
108		-16 1	+1 2	11 3	18 4	24 5	29 7	33 8	37 9	40 10	44 12	46 13	49 14	52 16	54 17	56 19	58 20	60 22	62 23	64 25	66 26	68 28	69 30	71 31	73 33	74 35	76 37	77 39	79 41	80 43	82 45	83 47	85 49	86 51								
109		-27	-3 2	+8 3	16 4	23 5	28 6	32 7	36 8	39 10	43 11	46 12	48 13	51 15	53 16	56 18	58 19	60 21	62 22	64 24	66 25	67 27	69 28	71 30	72 32	74 34	76 35	77 37	79 39	80 41	82 43	83 45	84 47	86 49								
110		-58	-9 1	+5 2	14 3	21 4	26 5	31 7	35 8	38 9	42 10	45 11	48 13	50 14	53 15	55 17	57 18	59 20	61 21	63 23	65 24	67 26	69 27	70 29	72 31	74 32	75 34	77 36	78 38	80 40	81 41	83 43	84 45	85 47								
111	-17 1	+1 2	11 3	19 4	24 5	29 6	34 7	37 8	41 10	44 11	47 12	49 13	52 15	54 16	57 17	59 19	61 20	63 22	65 23	67 25	68 26	70 28	72 29	73 31	75 33	77 34	78 36	80 38	81 40	82 42	84 44	85 46										
112	-29	-4 1	+8 2	16 3	23 4	28 6	32 7	36 8	40 9	43 10	46 11	49 13	51 14	54 15	56 16	58 18	60 19	62 21	64 22	66 24	68 25	70 27	71 28	73 30	75 31	76 33	78 35	79 37	81 38	82 40	84 42	85 44										
113	-10 1	+5 2	14 3	21 4	26 5	31 6	35 7	39 8	42 10	45 11	48 12	51 13	53 14	55 16	58 17	60 18	62 20	64 21	66 23	68 24	69 26	71 27	73 29	74 30	76 32	77 34	79 35	80 37	82 39	83 41	85 43											
114	-18 1	+1 2	11 3	19 4	25 5	30 6	34 7	38 9	41 10	44 11	47 12	50 14	53 15	55 16	57 17	59 19	61 20	63 22	65 23	67 24	69 26	71 27	72 29	74 31	76 32	77 34	79 36	80 38	82 39	83 41	85 43											
115	-31	-4 1	+8 2	17 3	23 4	28 5	33 6	37 7	40 8	44 9	47 11	49 12	52 13	54 14	57 15	59 17	61 18	63 19	65 21	67 22	69 23	70 25	72 26	74 28	75 29	77 31	78 33	80 34	81 36	83 38	84 40											
116	-10 1	+5 2	14 3	21 4	27 5	32 6	36 7	39 8	43 9	46 10	49 11	51 12	54 13	56 15	58 16	60 17	62 18	64 20	66 21	68 23	70 24	72 25	73 27	75 28	77 30	78 31	80 33	81 35	83 36	84 38												
117	-18 1	+1 1	12 2	19 3	25 4	30 5	35 6	38 7	42 8	45 9	48 11	51 12	53 13	55 14	58 15	60 16	62 18	64 19	66 20	68 22	70 23	71 24	73 26	75 27	76 29	78 30	79 32	81 33	82 35	84 37												
118	-31	-3 1	+9 2	17 3	24 4	29 5	33 6	37 7	41 8	44 9	47 10	50 11	52 12	55 13	57 14	59 16	62 17	64 18	65 19	67 21	69 22	71 23	73 25	74 26	76 28	78 29	79 31	81 32	82 34	84 35												
119		-9 1	+6 2	15 3	22 4	27 4	32 5	36 6	40 7	43 8	46 9	49 10	52 12	54 13	57 14	59 15	61 16	63 17	65 19	67 20	69 21	71 22	72 24	74 25	76 27	77 28	79 30	80 31	82 33	83 34												

WS TA B-0-5C
(11-73)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RELATIVE HUMIDITY and DEW POINT TABLE

Pressure 27 Inches of Mercury

For use at elevations between 1,900 and 3,900 feet above sea level
(In Alaska use at elevations between 1,700 and 3,600 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
30	-45 3	-17 12	-6 21	+2 30	8 39	13 49	17 58	21 68	24 78	27 89	30 99																														
31		-31 5	-13 14	-3 23	+5 32	10 41	15 50	19 60	22 69	25 79	28 89	31 99																													
32			-23 8	-8 17	0 25	+7 34	12 43	16 52	20 61	24 71	27 80	29 90	32 100																												
33			-43 2	-16 11	-5 19	+3 27	9 36	14 45	18 54	22 63	25 72	28 81	31 91	33 100																											
34				-29 5	-12 13	-2 21	+5 29	11 38	16 46	20 55	23 64	26 73	29 82	32 91	34 100																											
35					-21 8	-7 16	+1 23	8 31	13 40	17 48	21 57	25 65	28 74	30 83	33 91	35 100																											
36					-39 3	-15 10	-4 18	+4 26	10 33	15 42	19 50	23 58	26 66	29 75	31 83	34 91	36 100																											
37						-27 5	-10 13	0 20	+7 28	12 35	17 43	21 51	24 59	27 67	30 75	32 83	35 92	37 100																											
38						-57 1	-18 8	-6 15	+3 22	9 30	14 37	19 45	22 53	26 60	28 68	31 76	34 84	36 92	38 100																										
39							-33 3	-12 10	-2 17	+6 24	11 32	16 39	20 47	24 54	27 61	30 69	32 76	35 84	37 92	39 100																										
40								-23 6	-7 13	+2 19	8 26	14 34	18 41	22 48	25 55	28 62	31 69	33 77	36 84	38 92	40 100	41 100																							
41								-43 2	-15 8	-3 15	+5 22	11 28	16 35	20 42	23 49	26 56	29 63	32 70	34 77	37 85	39 92	41 100																							
42									-27 4	-9 11	0 17	+8 24	13 30	18 37	21 43	25 50	28 57	31 64	33 71	36 78	38 85	40 92	42 100																						
43									1	-18 7	-5 13	+4 19	10 26	15 32	19 38	23 45	26 51	29 58	32 64	34 71	37 78	39 85	41 93	43 100																					
44										-32 3	-11 9	-1 15	+7 21	12 27	17 33	21 39	24 46	28 52	30 59	33 65	36 72	38 79	40 86	42 93	44 100																				
45											-21 5	-6 11	+3 17	9 23	14 29	19 35	23 41	26 47	29 53	32 59	34 66	37 72	39 79	41 86	43 93	45 100	46 100																	
46											-38 2	-13 8	-2 13	+6 19	12 25	16 30	21 36	24 42	27 48	30 54	33 60	36 67	38 73	40 80	42 86	44 93	46 100																	
47												-24 4	-7 10	+2 15	9 21	14 26	18 32	22 37	26 43	29 49	32 55	34 61	37 67	39 74	41 80	43 87	45 93	47 100																
48												-46 1	-15 6	-3 12	+5 17	11 22	16 28	20 33	24 39	27 44	30 50	33 56	36 62	38 68	40 74	42 80	44 87	46 93	48 100														
49													-26 3	-9 8	+1 13	8 18	13 24	18 29	22 34	26 40	29 45	32 51	34 57	37 63	39 68	41 75	43 81	45 87	47 93	49 100												
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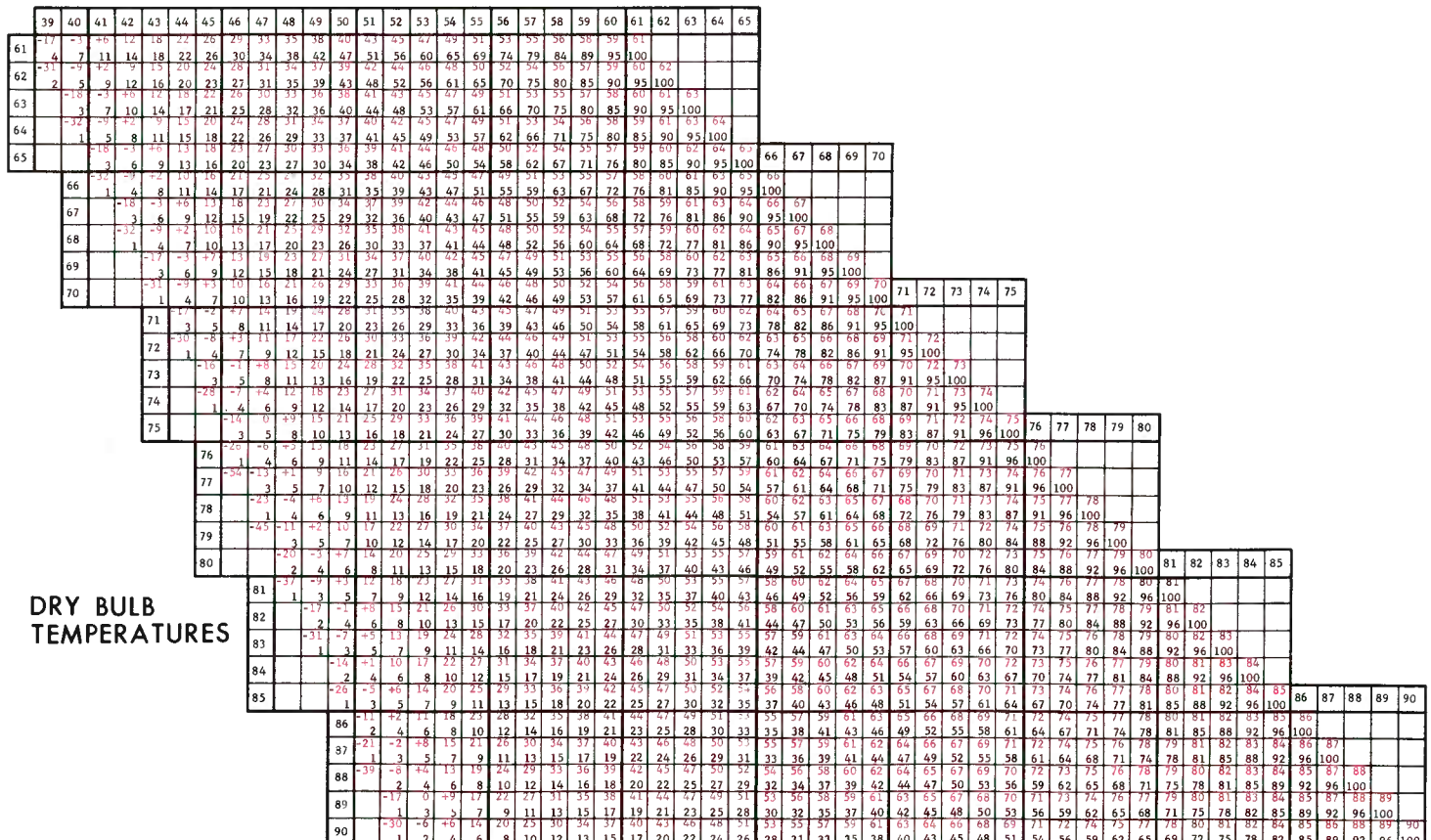
WET BULB TEMPERATURES



DRY BULB TEMPERATURES

WET BULB TEMPERATURES

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WET BULB TEMPERATURES

DRY BULB TEMPERATURES

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81												-40	-9	+4	12	19	24	28	32	36	39	42	45	47	49	52	54	56	58	60	61	63	65	67	68	70	71	73	74	76	77	78	80	81																														
												1	3	5	7	10	12	15	17	20	23	26	28	31	33	36	39	42	45	48	51	55	58	62	65	69	72	76	80	84	88	92	96	100																														
82													-18	-1	+9	16	22	27	31	34	38	41	44	46	49	51	53	55	57	59	61	63	64	66	68	69	71	72	74	75	77	78	79	81	82																														
													2	4	6	8	10	13	16	18	21	23	26	28	31	34	37	40	43	46	49	53	56	59	62	65	69	73	76	80	84	88	92	96	100																														
83													-34	-7	+5	13	20	25	29	33	36	40	43	45	48	50	52	54	56	58	60	62	64	66	67	69	70	72	73	75	76	78	79	80	82	83																														
													1	3	5	7	9	12	14	17	19	22	24	27	29	32	35	38	41	44	47	50	53	56	59	62	66	70	73	77	81	84	88	92	96	100																														
84														-15	+1	10	17	23	27	32	35	38	41	44	47	49	52	54	56	58	60	62	63	65	67	68	70	71	73	74	76	77	79	80	81	83	84																														
														2	4	6	8	10	13	15	17	20	22	25	27	30	33	35	38	41	44	47	50	53	56	59	63	66	70	73	77	80	84	88	92	96	100																														
85														-29	-5	+7	14	21	26	30	34	37	40	43	46	48	51	53	55	57	59	61	63	65	66	68	69	71	73	74	76	77	78	80	81	82	84	85																														
														1	3	5	7	9	11	14	16	19	21	23	26	28	31	33	36	39	42	45	47	50	54	57	60	63	66	70	73	77	81	84	88	92	96	100																														
86															-12	+2	11	18	24	28	32	36	39	42	45	48	50	52	54	57	59	60	62	64	66	67	69	71	72	74	75	77	78	79	81	82	83	85	86																														
															2	4	6	8	10	12	15	17	19	22	24	26	29	32	34	37	40	42	45	48	51	54	57	60	64	67	70	74	77	81	84	88	92	96	100																														
87															-24	-3	+8	16	22	27	31	35	38	41	44	47	49	52	54	56	58	60	62	64	65	67	69	70	72	73	75	76	78	79	80	82	83	84	86	87																														
															1	3	5	7	9	11	13	16	18	20	22	25	27	30	32	35	38	41	43	46	49	51	54	58	61	64	67	70	74	77	81	85	88	92	96	100																														
88															-50	-10	+4	13	19	25	29	33	37	40	43	46	48	51	53	55	57	59	61	63	65	66	68	70	71	73	74	76	77	79	80	81	83	84	85	87	88																														
																2	4	6	8	10	12	14	16	19	21	23	26	28	30	33	35	38	41	43	46	49	52	55	58	61	64	67	71	74	78	81	85	88	92	96	100																														
89																-19	-1	+10	17	23	28	32	36	39	42	45	48	50	52	55	57	59	61	62	64	66	68	69	71	72	74	76	77	78	80	81	83	84	85	86	88	89																														
																1	3	5	7	9	11	13	15	17	19	22	24	26	29	31	34	36	39	41	44	47	50	52	55	58	61	65	68	71	74	78	81	85	88	92	96	100																														
90																-37	-7	+6	14	21	26	30	34	38	41	44	47	49	52	54	56	58	60	62	64	66	67	69	71	72	74	75	77	78	79	81	82	84	85	86	87	89	90																														
																2	4	6	8	10	12	14	16	18	20	22	25	27	29	32	34	37	39	42	45	47	50	53	56	59	62	65	68	71	75	78	82	85	89	92	96	100																														

WET BULB TEMPERATURES

DRY BULB TEMPERATURES	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
91	-15	+1	11	18	24	29	33	37	40	43	46	48	51	53	55	57	59	61	63	65	67	68	70	72	73	75	76	78	79	81	82	83	85	86	87	88	90	91				
	1	3	5	7	9	11	13	15	17	19	21	23	25	28	30	32	35	37	40	42	45	48	51	53	56	59	62	65	68	72	75	78	82	85	89	92	96	100				
92	-28	-4	+8	16	22	27	31	35	39	42	45	47	50	52	55	57	59	61	63	65	66	68	70	71	73	74	76	77	79	80	82	83	84	86	87	88	90	91	92			
	1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	31	33	35	38	40	43	46	48	51	54	57	60	63	66	69	72	75	78	82	85	89	92	96	100			
93		-11	+4	13	20	25	30	34	38	41	44	47	49	52	54	56	58	60	62	64	66	68	69	71	72	74	76	77	78	80	81	83	84	85	87	88	89	91	92	93		
		2	3	5	7	9	11	12	14	16	18	20	23	25	27	29	31	34	36	38	41	43	46	49	51	54	57	60	63	66	69	72	75	79	82	85	89	93	96	100		
94		-21	-1	+10	17	23	28	32	36	40	43	46	48	51	53	55	58	60	62	63	65	67	69	70	72	74	75	77	78	80	81	82	84	85	86	88	89	90	92	93	94	
		1	3	4	6	8	10	11	13	15	17	19	21	23	25	28	30	32	34	37	39	41	44	47	49	52	55	57	60	63	66	69	72	76	79	82	86	89	93	96	100	
95		-43	-7	+6	14	21	26	31	35	39	42	45	47	50	52	55	57	59	61	63	65	67	68	70	72	73	75	76	78	79	81	82	83	85	86	87	89	90	91	93	94	95
			2	4	5	7	9	10	12	14	16	18	20	22	24	26	28	30	33	35	37	40	42	45	47	50	52	55	58	61	64	66	70	73	76	79	82	86	89	93	96	100
96			-16	+1	11	19	25	29	34	37	41	44	47	49	52	54	56	58	60	62	64	66	68	70	71	73	74	76	77	79	80	82	83	85	86	87	88	90	91	92	94	95	
			1	3	4	6	8	9	11	13	15	17	19	21	23	25	27	29	31	33	35	38	40	43	45	48	50	53	55	58	61	64	67	70	73	76	79	82	86	89	93	96
97			-30	-4	+8	16	23	28	32	36	40	43	46	48	51	53	56	58	60	62	64	66	67	69	71	72	74	76	77	79	80	81	83	84	86	87	88	90	91	92	93	95	
			1	2	4	5	7	9	10	12	14	16	17	19	21	23	25	27	29	32	34	36	38	41	43	45	48	51	53	56	59	61	64	67	70	73	76	79	83	86	89	93
98				-11	+4	13	20	26	31	35	38	42	45	48	50	53	55	57	59	61	63	65	67	69	70	72	74	75	77	78	80	81	83	84	85	87	88	89	91	92	93	94	
				1	3	5	6	8	9	11	13	15	16	18	20	22	24	26	28	30	32	34	37	39	41	44	46	48	51	54	56	59	62	64	67	70	73	76	80	83	86	89
99				-21	-1	+10	18	24	29	33	37	41	44	47	49	52	54	57	59	61	63	65	66	68	70	72	73	75	76	78	79	81	82	84	85	86	88	89	90	92	93	94	
				1	2	4	5	7	9	10	12	14	15	17	19	21	23	25	27	29	31	33	35	37	39	42	44	46	49	51	54	57	59	62	65	68	71	74	77	80	83	86
100				-43	-7	+7	15	22	27	32	36	40	43	46	49	51	54	56	58	60	62	64	66	68	70	71	73	74	76	78	79	81	82	83	85	86	87	89	90	91	93	94	
					2	3	5	6	8	9	11	13	14	16	18	20	21	23	25	27	29	31	33	35	38	40	42	44	47	49	52	54	57	60	62	65	68	71	74	77	80	83	
101					-15	+2	12	20	26	30	35	38	42	45	48	50	53	55	57	60	62	64	65	67	69	71	72	74	76	77	79	80	82	83	84	86	87	89	90	91	92	94		
					1	3	4	5	7	8	10	12	13	15	17	18	20	22	24	26	28	30	32	34	36	38	40	43	45	47	50	52	55	57	60	63	65	68	71	74	77	80	
102					-28	-3	+9	17	24	29	33	37	41	44	47	50	52	55	57	59	61	63	65	67	69	70	72	74	75	77	78	80	81	83	84	86	87	88	90	91	92	93		
					1	2	3	5	6	8	9	11	12	14	16	17	19	21	23	25	26	28	30	32	34	36	39	41	43	45	48	50	53	55	58	60	63	66	68	71	74	77	
103						-10	+5	15	21	27	32	36	40	43	46	49	51	54	56	58	60	63	64	66	68	70	72	73	75	76	78	80	81	82	84	85	87	88	89	91	92	93		
						1	3	4	6	7	8	10	12	13	15	16	18	20	21	23	25	27	29	31	33	35	37	39	41	43	46	48	50	53	55	58	60	63	66	69	71	74	
104						-19	+1	12	19	25	30	35	38	42	45	48	51	53	55	58	60	62	64	66	68	69	71	73	75	76	78	79	81	82	84	85	86	88	89	90	92	93		
						1	2	3	5	6	8	9	11	12	14	15	17	19	20	22	24	26	28	29	31	33	35	37	40	42	44	46	48	51	53	56	58	61	63	66	69	72	
105						-37	-5	+8	17	23	29	33	37	41	44	47	50	52	55	57	59	61	63	65	67	69	71	72	74	76	77	79	80	82	83	85	86	87	89	90	91	93		
							2	3	4	6	7	8	10	11	13	14	16	18	19	21	23	24	26	28	30	32	34	36	38	40	42	44	47	49	51	54	56	59	61	64	66	69	
106							-12	+4	14	21	27	32	36	40	43	46	49	52	54	56	59	61	63	65	67	69	70	72	74	75	77	79	80	82	83	84	86	87	89	90	91	93		
							1	2	4	5	6	8	9	11	12	14	15	17	18	20	22	23	25	27	29	30	32	34	36	38	40	43	45	47	49	52	54	56	59	61	64	67	
107							-23	-1	+11	19	25	30	35	38	42	45	48	51	53	56	58	60	62	64	66	68	70	72	73	75	77	78	80	81	83	84	86	87	88	90	91	92		
							1	2	3	4	6	7	8	10	11	13	14	16	17	19	20	22	24	26	27	29	31	33	35	37	39	41	43	45	47	50	52	54	57	59	62	64	
108							-49	-7	+7	16	23	29	33	37	41	44	47	50	53	55	57	60	62	64	66	68	70	71	73	75	76	78	79	81	82	84	85	87	88	89	91	92		
								1	3	4	5	6	8	9	10	12	13	15	16	18	19	21	23	24	26	28	30	31	33	35	37	39	41	43	46	48	50	52	55	57	59	62	
109								-15	+3	13	21	27	32	36	40	43	46	49	52	54	57	59	61	63	65	67	69	71	73	74	76	78	79	81	82	84	85	86	88	89	91	92		
								1	2	3	5	6	7	8	10	11	13	14	15	17	18	20	22	23	25	27	28	30	32	34	36	38	40	42	44	46	48	50	53	55	57	60	
110								-28	-2	+10	19	25	30	35	39	42	45	48	51	54	56	58	61	63	65	67	69	70	72	74	76	77	79	80	82	83	85	86	88	89	90	92		
									2	3	4	5	6	8	9	10	12	13	15	16	18	19	21	22	24	25	27	29	31	32	34	36	38	40	42	44	46	48	51	53	55	58	
111									-8	+7	16	23	29	33	37	41	44	48	50	53	56	58	60	62	64	66	68	70	72	73	75	77	78	80	81	83	84	86	87	89	90	91		
									1	2	3	5	6	7	8	10	11	12	14	15	17	18	20	21	23	24	26	28	29	31	33	35	37	39	41	43	45	47	49	51	53	56	
112									-17	+2	13	21	27	32	36	40	43	47	50	52	55	57	60	62	64	66	68	70	71	73	75	76	78	80	81	83	84	86	87	88	90	91		
									1	2	3	4	5	7	8	9	10	12	13	14	16	17	19	20	22	23	25	26	28	30	32	33	35	37	39	41	43	45	47	49	51	54	
113									-32	-3	+10	18	25	30	35	39	42	46	49	52	54	57	59	61	63	65	67	69	71	73	74	76	78	79	81	82	84	85	87	88	90	91		
										1	2	4	5	6	7	8	10	11	12	14	15	16	18	19	21	22	24	25	27	29	30	32	34	36	37	39	41	43	45	47	50	52	
114										-10	+6	16	23	29	33	38	41	45	48	51	53	56	58	61	63	65	67	69	71	72	74	76	77	79	81	82	84	85	86	88	89	91		
										1	2	3	4	5	7	8	9	10	11	13	14	15	17	18	20	21	23	24	26	27	29	31	32	34	36	38	40	42	44	46	48	50	
115										-19	+2	13	21	27	32	36	40	44	47	50	53	55	58	60	62	64	66	68	70	72	74	75	77	79	80	82	83	85	86	88	89	90		
										1	2	3	4	5	6	7	8	10	11	12	13	15	16	17	19	20	22	23	25	26	28	30	31	33	35	36	38	40	42	44	46	48	
116											-37	-3	+10	18	25	30	35	39	43	46	49	52	55	57	59	62	64	66	68	70	71	73	75	77	78	80	81	83	84	86	87	89	90	
											1	2	3	4	6	7	8	9	10	11	13	14	15	17	18	19	21	22	24	25	27	28	30	32	33	35	37	39	41	42	44	46	
117											-10	+6	16	23	29	34	38	42	45	48	51	54	56	59	61	63	65	67	69	71	73	75	76	78	80	81	83	84	86	87	89	90	
											1	2	3	4	5	6	7	8	10	11	12	13	14	16	17	18	20	21	23	24	26	27	29	30	32	34	36	37	39	41	43	45	
118											-20	+2	13	21	27	32	37	41	44	47	50	53	56	58	60	63	65	67	69	71	72	74	76	78	79	81	82	84	85	87	88	90	
											1	1	2	3	5	6	7	8	9	10	11	12	14	15	16	18	19	20	22	23	25	26	28	29	31	33	34	36	38	39	41	43	
119											-40	-4	+10	19	25	31	35	40	43	47	50	52	55	58	60	62	64	66	68	70	72	74	76	77	79	80	82	84	85	87	88	89	
												1	2	3	4	5	6	7	8	9	11	12	13	14	15	17	18	19	21	22	24	25	27	28	30	31	33	35	36	38	40	42	

WS TA B-0-5D
(10-73)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RELATIVE HUMIDITY and DEW POINT TABLE

Pressure 29 Inches of Mercury

For use at elevations between 501 and 1,900 feet above sea level
(In Alaska use at elevations between 301 and 1,700 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
30	-25 8	-10 17	0 27	+7 37	12 46	16 57	20 67	24 77	27 88	30 99																														
31	-57 1	-19 10	-6 20	+2 29	9 38	14 48	18 58	22 68	25 78	28 89	31 99																													
32		-36 4	-13 13	-3 22	+5 31	11 40	15 50	20 60	23 69	26 79	29 90	32 100																												
33			-25 7	-9 15	0 24	+7 33	13 42	17 52	21 61	25 71	28 80	30 90	33 100																										
34			-56 1	-18 9	-5 18	+3 26	9 35	14 44	19 53	23 62	26 72	29 81	32 91	34 100																										
35				-34 4	-13 12	-2 20	+6 29	11 37	16 46	20 55	24 64	27 73	30 82	33 91	35 100																										
36					-24 6	-8 14	+1 22	8 31	14 39	18 48	22 56	25 65	28 74	31 82	34 91	36 100																										
37					-50 1	-17 9	-4 17	+4 25	10 33	15 41	20 49	24 58	27 66	30 74	32 83	35 91	37 100																										
38						-31 4	-11 11	0 19	+7 27	13 35	17 43	21 51	25 59	28 67	31 75	33 83	36 91	38 100																										
39							-21 7	-6 14	+3 21	9 29	15 37	19 44	23 52	26 60	29 67	32 75	34 83	37 92	39 100																										
40							-42 2	-14 9	-2 16	+6 23	12 31	17 38	21 46	24 53	28 61	30 68	33 76	36 84	38 92	40 100																										
41								-26 5	-9 11	+1 18	8 26	14 33	18 40	22 47	26 54	29 61	32 69	34 77	37 84	39 92	41 100																										
42									-18 7	-4 14	+5 21	11 28	16 34	20 41	24 48	27 55	30 62	33 70	35 77	38 85	40 92	42 100																										
43									-33 3	-11 9	0 16	+8 23	13 29	18 36	22 42	25 49	28 56	31 63	34 70	36 78	39 85	41 92	43 100																										
44										-21 5	-6 12	+3 18	10 24	15 31	20 37	23 44	27 50	30 57	33 64	35 71	38 78	40 85	42 93	44 100																										
45										-42 2	-13 8	-1 14	+6 20	12 26	17 32	21 39	25 45	28 51	31 58	34 65	36 72	39 78	41 86	43 93	45 100																										
46											-25 4	-7 10	+2 16	9 22	14 28	19 34	23 40	26 46	30 52	32 59	35 65	38 72	40 79	42 86	44 93	46 100																										
47											-56 1	-16 6	-3 12	+5 18	11 23	17 29	21 35	25 41	28 47	31 53	34 60	36 66	39 73	41 79	43 86	45 93	47 100																										
48												-29 3	-10 8	+1 14	8 19	14 25	19 31	23 36	26 42	29 48	32 54	35 60	38 67	40 73	42 80	44 86	46 93	48 100																										
49													-19 5	-5 10	+4 16	11 21	16 26	20 32	24 38	28 43	31 49	34 55	36 61	39 67	41 74	43 80	45 87	47 93	49 100																										
50													-37 2	-12 7	-1 12	+7 17	13 22	18 28	22 33	26 39	29 44	32 50	35 56	38 62	40 68	42 74	44 80	46 87	48 93	50 100																										
51														-23 4	-6 9	+3 14	10 19	15 24	20 29	24 35	28 40	31 46	34 51	36 57	39 63	41 69	43 75	45 81	47 87	49 93	51 100																										
52														-47 1	-14 6	-2 11	+6 15	13 20	18 25	22 31	26 36	29 41	32 47	35 52	38 58	40 63	42 69	44 75	46 81	48 87	50 94	52 100																										
53															-27 3	-8 7	+2 12	9 17	15 22	20 27	24 32	27 37	31 42	34 48	36 53	39 58	41 64	43 70	46 76	48 82	49 88	51 94	53 100																										
54																-17 5	-3 9	+6 14	12 19	17 23	22 28	26 33	29 38	32 43	35 49	38 54	40 59	42 65	45 70	47 76	49 82	50 88	52 94	54 100																										
55																-32 2	-10 6	+1 11	9 15	15 20	20 25	24 30	27 34	31 39	34 44	36 49	39 55	41 60	44 65	46 71	48 76	50 82	52 88	53 94	55 100																										
56																	-19 4	-4 8	+5 13	12 17	17 21	22 26	26 31	29 36	32 40	35 45	38 50	40 55	43 61	45 66	47 71	49 77	51 82	53 88	54 94	56 100																										
57																	-37 1	-11 6	+1 10	8 14	14 18	19 23	24 27	27 32	31 37	34 41	37 46	39 51	42 56	44 61	46 67	48 72	50 77	52 83	54 88	55 94	57 100																										
58																		-21 3	-5 7	+5 11	11 16	17 20	22 24	26 29	29 33	32 38	35 42	38 47	40 52	43 57	45 62	47 67	49 72	51 78	53 83	55 89	56 94	58 100																										
59																		-43 1	-12 5	0 9	+8 13	14 17	19 21	24 25	28 30	31 34	34 39	37 43	39 48	42 53	44 58	46 63	48 68	50 73	52 78	54 83	56 89	57 94	59 100																										
60																			-24 3	-6 7	+4 10	11 14	17 18	22 23	26 27	29 31	33 35	36 40	38 44	41 49	43 54	45 58	47 63	49 68	51 73	53 78	55 84	57 89	58 94	60 100																										

WS TA B-0-5E
(11-73)

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

RELATIVE HUMIDITY and DEW POINT TABLE

Pressure 30 Inches of Mercury

For use at elevations between 0 and 500 feet above sea level
(In Alaska use at elevations between 0 and 300 feet above sea level)

Values in the body of the table are relative humidities (in percent) and dew points (in deg. Fahr.), with respect to water, for indicated values of wet and dry bulb temperatures in degrees Fahrenheit.

HOW TO USE THE TABLE

Locate at the top of the column the reading corresponding to the wet bulb temperature. Locate at the left side of the table the reading corresponding to the dry bulb temperature. Follow down the column under the wet bulb temperature, and across from the dry bulb temperature; at the intersection of these two columns will be found the relative humidity (%) in black and the dew point (°F.) in red.

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
30	-31 6	-12 15	-1 25	+6 35	11 45	16 56	20 66	24 77	27 88	30 99																														
31		-23 8	-8 18	+1 27	8 37	13 47	18 57	22 68	25 78	28 89	31 99																													
32		-48 2	-16 11	-4 20	+4 30	10 39	15 49	19 59	23 69	26 79	29 89	32 100																												
33			-31 5	-12 14	-1 23	+6 32	12 41	17 51	21 60	24 70	28 80	30 90	33 100																											
34				-22 8	-7 16	+2 25	9 34	14 43	18 52	22 62	26 71	29 81	32 90	34 100																											
35				-47 2	-16 10	-4 19	+5 27	11 36	16 45	20 54	24 63	27 72	30 81	33 91	35 100																										
36					-30 5	-11 13	0 21	+7 29	13 38	18 47	22 55	25 64	28 73	31 82	34 91	36 100																										
37						-21 7	-6 15	+3 23	9 31	15 40	19 48	23 57	26 65	29 74	32 82	35 91	37 100																										
38						-42 2	-14 10	-2 18	+6 25	12 33	17 42	21 50	25 58	28 66	31 74	33 83	36 91	38 100																										
39							-27 5	-9 12	+1 20	8 28	14 35	19 43	22 51	26 59	29 67	32 75	34 83	37 92	39 100																										
40								-18 7	-4 15	+4 22	11 30	16 37	20 45	24 52	27 60	30 68	33 76	35 84	38 92	40 100																										
41								-36 3	-12 10	-1 17	+7 24	13 32	18 39	22 46	25 53	29 61	31 68	34 76	37 84	39 92	41 100																										
42									-23 5	-7 12	+3 19	10 26	15 33	20 40	23 47	27 54	30 62	33 69	35 77	38 84	40 92	42 100																										
43									-49 1	-15 8	-2 14	+6 21	12 28	17 35	21 41	25 48	28 55	31 62	34 70	36 77	39 85	41 92	43 100																										
44										-29 4	-9 10	+2 17	9 23	14 29	19 36	23 43	26 49	29 56	32 63	35 70	37 78	40 85	42 92	44 100																										
45											-18 6	-4 12	+5 19	11 25	16 31	21 37	24 44	28 51	31 57	34 64	36 71	39 78	41 85	43 93	45 100																										
46											-35 2	-11 8	0 14	+7 20	13 26	18 32	22 39	26 45	29 52	32 58	35 65	37 72	40 79	42 86	44 93	46 100																										
47												-22 5	-6 10	+3 16	10 22	16 28	20 34	24 40	27 46	31 53	33 59	36 66	39 72	41 79	43 86	45 93	47 100																										
48												-45 1	-14 7	-2 12	+6 18	13 24	18 29	22 35	26 41	29 47	32 54	35 60	37 66	40 73	42 79	44 86	46 93	48 100																										
49													-27 3	-8 9	+2 14	9 20	15 25	20 31	24 37	27 42	30 48	33 54	36 61	39 67	41 73	43 80	45 86	47 93	49 100																										
50														-17 5	-3 10	+5 16	12 21	17 27	21 32	25 38	29 44	32 49	35 55	37 61	40 68	42 74	44 80	46 87	48 93	50 100																										
51																-33 2	-11 7	+1 12	8 17	14 23	19 28	23 34	27 39	30 45	33 50	36 56	39 62	41 68	43 74	45 81	47 87	49 93	51 100																										
52																	-21 4	-5 9	+4 14	11 19	17 24	21 29	25 35	29 40	32 46	35 51	37 57	40 63	42 69	44 75	46 81	48 87	50 94	52 100																										
53																		-42 1	-13 6	-1 11	+8 16	14 21	19 26	23 31	27 36	30 41	33 47	36 52	39 58	41 64	43 69	45 75	47 81	49 87	51 94	53 100																										
54																			-25 3	-7 8	+3 12	11 17	16 22	21 27	25 32	28 37	32 42	35 48	37 53	40 59	42 64	44 70	47 76	49 82	50 88	52 94	54 100																										
55																			-57	-15 5	-2 9	+7 14	13 19	18 24	23 28	27 33	30 38	33 43	36 49	39 54	41 59	43 65	46 70	48 76	50 82	51 88	53 94	55 100																										
56																				-29 2	-8 7	+3 11	10 16	16 20	21 25	25 30	28 35	32 39	35 44	37 50	40 55	42 60	45 65	47 71	49 77	51 82	53 88	54 94	56 100																										
57																					-17 4	-3 8	+6 13	13 17	18 22	23 26	27 31	30 36	33 41	36 45	39 50	41 56	44 61	46 66	48 71	50 77	52 83	54 88	55 94	57 100																										
58																					-33 2	-10 6	+2 10	10 14	16 19	21 23	25 28	28 32	32 37	35 42	38 46	40 51	43 56	45 61	47 67	49 72	51 77	53 83	55 88	56 94	58 100																										
59																						-19 3	-4 7	+6 12	13 16	18 20	23 24	27 29	30 33	33 38	36 43	39 47	41 52	44 57	46 62	48 67	50 72	52 78	54 83	56 89	57 94	59 100																										
60																						-38 1	-11 5	+1 9	9 13	15 17	20 21	25 26	29 30	32 34	35 39	38 44	40 48	43 53	45 58	47 63	49 68	51 73	53 78	55 83	57 89	58 94	60 100

WET BULB TEMPERATURES

DRY BULB TEMPERATURES

	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
61	-21 3	-4 7	+5 11	12 15	18 19	23 23	27 27	30 31	34 36	36 40	39 44	42 49	44 54	46 58	48 63	50 68	52 73	54 78	56 84	58 89	59 94	61 100				
62	-44 1	-12 4	+1 8	9 12	15 16	20 20	25 24	29 28	32 32	35 37	38 41	41 45	43 50	45 54	48 59	50 64	52 69	54 74	55 79	57 84	59 89	60 95	62 100			
63		-23 2	-5 6	+5 10	12 14	18 17	23 21	27 25	31 29	34 33	37 38	39 42	42 46	44 51	47 55	49 60	51 64	53 69	55 74	56 79	58 84	60 89	61 95	63 100		
64		-50 1	-13 4	0 8	+9 11	15 15	21 19	25 23	29 26	32 30	35 34	38 39	41 43	43 47	46 51	48 56	50 60	52 65	54 70	56 74	57 79	59 84	61 89	62 95	64 100	
65			-25 2	-5 6	+5 9	12 13	18 16	23 20	27 24	31 28	34 31	37 35	40 39	42 44	45 48	47 52	49 56	51 61	53 65	55 70	57 75	59 80	60 85	62 90	63 95	65 100
66	-57	-13 4	0 7	+9 10	15 14	21 18	25 21	29 25	33 29	36 32	39 36	41 40	44 44	46 49	48 53	50 57	52 62	54 66	56 71	58 75	60 80	61 85	63 90	64 95	66 100
67		-26 2	-6 5	+5 8	12 12	18 15	23 19	27 22	31 26	34 30	37 34	40 37	43 41	45 45	47 49	50 54	52 58	54 62	55 66	57 71	59 76	61 80	62 85	64 90	65 95	67 100
68			-14 3	0 7	+9 10	16 13	21 17	25 20	29 24	33 27	36 31	39 34	42 38	44 42	47 46	49 50	51 54	53 58	55 63	57 67	58 71	60 76	62 81	63 85	65 90	67 95	68 100
69			-26 2	-6 5	+5 8	13 11	19 14	23 18	28 21	31 25	35 28	38 32	41 35	43 39	46 43	48 47	50 51	52 55	54 59	56 63	58 67	60 72	61 76	63 81	64 85	66 90	68 95	69 100
70				-14 3	0 6	+9 9	16 12	21 16	26 19	30 22	33 26	36 29	39 33	42 36	45 40	47 44	49 48	51 51	53 55	55 60	57 64	59 68	61 72	62 77	64 81	66 86	67 90	69 95	70 100
71				-26 2	-5 5	+5 8	13 11	19 14	24 17	28 20	32 23	35 27	38 30	41 34	44 37	46 41	48 45	51 48	53 52	55 56	56 60	58 64	60 68	62 73	63 77	65 81	67 86	68 90	70 95	71 100
72					-13 3	+1 6	10 9	16 12	22 15	26 18	30 21	34 24	37 29	40 31	43 35	45 38	47 42	50 45	52 49	54 53	56 57	58 61	59 65	61 69	63 73	64 77	66 82	68 86	69 91	71 95	72 100
73					-26 2	-5 4	+6 7	13 10	19 13	24 16	29 19	32 22	36 25	39 29	41 32	44 35	47 39	49 42	51 46	53 50	55 53	57 57	59 61	61 65	62 69	64 73	66 77	67 82	69 86	70 91	72 95	73 100
74						-13 3	+1 6	10 8	17 11	22 14	27 17	31 20	34 23	37 26	40 30	43 33	46 36	48 40	50 43	52 47	54 50	56 54	58 58	60 62	62 66	63 70	65 74	67 78	68 82	70 86	71 91	73 95	74 100
75						-25 2	-4 4	+6 7	14 10	20 12	25 15	29 18	33 21	36 24	39 27	42 31	45 34	47 37	49 40	52 44	54 47	56 51	58 55	59 58	61 62	63 66	65 70	66 74	68 78	69 82	71 87	72 91	74 95	75 100
76	-57	-12 3	+2 5	11 8	17 11	23 14	27 16	31 19	35 22	38 25	41 28	44 31	46 35	49 38	51 41	53 45	55 48	57 52	59 55	61 59	62 63	64 66	66 70	67 74	69 78	70 82	72 87	73 91	75 95	76 100
77		-23 2	-3 4	+7 7	15 9	21 12	25 15	30 18	33 20	37 23	40 26	43 29	45 32	48 35	50 39	52 42	54 45	56 49	58 52	60 56	62 59	63 63	65 67	67 71	68 75	70 79	71 83	73 87	74 91	76 96	77 100
78		-49	-11 3	+3 5	12 8	18 10	23 13	28 16	32 19	35 21	39 24	41 27	44 30	47 33	49 36	51 39	53 43	56 46	57 49	59 53	61 56	63 60	65 63	66 67	68 71	69 75	71 79	72 83	74 87	75 91	77 96	78 100
79			-21 2	-2 4	+8 6	15 9	21 12	26 14	30 17	34 20	37 22	40 25	43 28	46 31	48 34	51 37	53 40	55 43	57 47	59 50	61 53	62 57	64 60	66 64	67 68	69 71	70 75	72 79	73 83	75 87	76 91	78 96	79 100
80			-43	-9 3	+4 5	12 8	19 10	24 13	29 15	33 18	36 21	39 23	42 26	45 29	47 32	50 35	52 38	54 41	56 44	58 47	60 50	62 54	64 57	65 61	67 64	68 68	70 72	72 75	73 79	74 83	76 87	77 91	79 96	80 100
81		-19 2	-1 4	+9 6	16 9	22 11	27 14	31 16	35 19	38 21	41 24	44 27	46 30	49 33	51 35	53 38	55 42	57 45	59 48	61 51	63 54	65 58	66 61	68 65	70 68	71 72	73 76	74 80	76 83	77 87	78 91	80 96	81 100
82	-37 1	-7 3	+5 5	13 7	20 10	25 12	29 15	33 17	37 20	40 22	43 25	45 28	48 31	50 33	53 36	55 39	57 42	59 45	61 48	62 52	64 55	66 58	68 62	69 65	71 69	72 72	74 76	75 80	77 84	78 88	79 92	81 96	82 100
83	-16 2	0 4	+10 6	17 9	23 11	28 13	32 16	35 18	39 21	42 23	44 26	47 29	50 31	52 34	54 37	56 40	58 43	60 46	62 49	64 52	65 55	67 59	69 62	70 65	72 69	73 73	75 76	76 80	78 84	79 83	80 92	82 96	83 100
84	-31 1	-6 3	+6 5	14 7	21 10	26 12	30 14	34 17	37 19	41 22	43 24	46 27	49 29	51 32	53 35	55 38	57 41	59 43	61 46	63 50	65 53	67 56	68 59	70 62	71 66	73 69	74 73	76 76	77 80	79 84	80 88	81 92	83 96	84 100
85	-14 2	+2 4	11 6	18 8	24 11	28 13	33 15	36 18	39 20	42 22	45 25	48 28	50 30	53 33	55 36	57 38	59 41	61 44	63 47	64 50	66 53	68 56	69 60	71 63	72 66	74 70	75 73	77 77	78 80	80 84	81 88	82 92	84 96	85 100
86	-26 1	-4 3	+8 5	15 7	22 9	27 12	31 14	35 16	38 18	41 21	44 23	47 26	49 28	52 31	54 34	56 36	58 39	60 42	62 45	64 48	66 51	67 54	69 57	70 60	72 63	74 67	75 70	77 73	78 77	79 81	81 84	82 88	83 92	85 96	86 100
87		-11 2	+3 4	12 6	19 8	25 10	29 13	33 15	37 17	40 19	43 22	46 24	49 27	51 29	53 32	55 34	58 37	59 40	61 42	63 45	65 48	67 51	68 54	70 57	72 60	73 64	75 67	76 70	78 74	79 77	80 81	82 84	83 88	84 92	86 96	87 100
88		-22 1	-2 3	+9 5	17 7	23 9	28 11	32 13	36 16	39 18	42 20	45 22	48 25	50 27	53 30	55 32	57 35	59 38	61 40	63 43	64 46	66 49	68 52	70 55	71 58	73 61	74 64	76 67	77 71	79 74	80 77	81 81	83 85	84 88	85 92	87 96	88 100
89		-45	-8 2	+5 4	14 6	20 8	26 10	30 12	34 14	38 17	41 19	44 21	47 23	49 26	52 28	54 30	56 33	58 36	60 38	62 41	64 44	66 46	67 49	69 52	71 55	72 58	74 61	75 64	77 68	78 71	80 74	81 78	82 81	84 85	85 88	86 92	88 96	89 100
90			-17 1	0 3	+11 5	18 7	24 9	29 11	33 13	37 15	40 17	43 20	46 22	48 24	51 26	53 29	55 31	58 34	60 36	62 39	63 41	65 44	67 47	69 50	70 53	72 55	73 58	75 62	76 65	78 68	79 71	81 74	82 78	84 81	85 85	86 89	87 92	89 96	90 100

WET BULB TEMPERATURES

DRY BULB TEMPERATURES	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
91	-34	-5	+7	15	22	27	31	35	39	42	45	48	50	53	55	57	59	61	63	65	66	68	70	71	73	75	76	78	79	80	82	83	85	86	87	88	90	91				
	1	2	4	6	8	10	12	14	16	18	20	23	25	27	29	32	34	37	39	42	45	47	50	53	56	59	62	65	68	71	75	78	82	85	89	92	96	100				
92		-13	+3	12	19	25	30	34	37	41	44	47	49	52	54	56	58	60	62	64	66	68	69	71	73	74	76	77	79	80	82	83	84	86	87	88	89	91	92			
		2	3	5	7	9	11	13	15	17	19	21	23	26	28	30	33	35	37	40	43	45	48	51	53	56	59	62	65	68	72	75	78	82	85	89	92	96	100			
93		-26	-3	+9	17	23	28	32	36	40	43	46	48	51	53	56	58	60	62	64	65	67	69	71	72	74	75	77	78	80	81	83	84	85	87	88	89	91	92	93		
		1	3	4	6	8	10	12	14	16	18	20	22	24	26	28	31	33	36	38	41	43	46	48	51	54	57	60	63	66	69	72	75	78	82	85	89	93	96	100		
94			-10	+5	14	21	26	31	35	38	42	45	48	50	53	55	57	59	61	63	65	67	68	70	72	73	75	76	78	79	81	82	84	85	86	88	89	90	92	93	94		
			2	3	5	7	9	11	13	14	16	18	21	23	25	27	29	31	34	36	39	41	44	46	49	52	54	57	60	63	66	69	72	75	79	82	85	89	93	96	100		
95			-20	0	+11	18	24	29	33	37	41	44	47	49	52	54	56	59	61	63	64	66	68	70	71	73	75	76	78	79	81	82	83	85	86	87	89	90	91	93	94	96	95
			1	3	4	6	8	10	12	13	15	17	19	21	23	25	28	30	32	34	37	39	42	44	47	49	52	55	57	60	63	66	69	72	76	79	82	86	89	93	100		
96			-39	-6	+7	15	22	27	32	36	39	43	46	48	51	53	56	58	60	62	64	66	68	69	71	73	74	76	77	79	80	82	83	84	86	87	88	90	91	92	94	95	
				2	4	5	7	9	10	12	14	16	18	20	22	24	26	28	30	33	35	37	40	42	45	47	50	52	55	58	61	64	67	70	73	76	79	82	86	89	93	96	
97				-14	+2	12	20	25	30	35	38	42	45	48	50	53	55	57	59	61	63	65	67	69	71	72	74	75	77	78	80	81	83	84	85	87	88	89	91	92	93	95	
				1	3	4	6	8	10	11	13	15	17	19	21	23	25	27	29	31	33	36	38	40	43	45	48	50	53	55	58	61	64	67	70	73	76	79	83	86	89	93	
98				-28	-3	+9	17	23	29	33	37	40	44	47	49	52	54	57	59	61	63	65	67	68	70	72	73	75	77	78	80	81	82	84	85	87	88	89	91	92	93	94	
				1	2	4	5	7	9	10	12	14	16	18	19	21	23	25	27	30	32	34	36	38	41	43	46	48	51	53	56	59	61	64	67	70	73	76	79	83	86	89	
99					-10	+5	14	21	27	32	36	39	43	46	48	51	54	56	58	60	62	64	66	68	70	71	73	75	76	78	79	81	82	84	85	86	88	89	90	92	93	94		
					1	3	5	6	8	9	11	13	15	16	18	20	22	24	26	28	30	32	34	37	39	41	44	46	48	51	54	57	59	62	65	67	70	73	76	80	83	86	
100					-20	0	+11	19	25	30	34	40	42	45	48	50	53	55	57	60	62	64	66	68	69	71	73	74	76	77	79	80	82	83	85	86	87	89	90	91	93	94	94	83	
					1	2	4	5	7	9	10	12	14	15	17	19	21	23	25	27	29	31	33	35	37	39	42	44	46	49	51	54	57	59	62	65	68	71	74	77	80	83	
101					-40	-6	+8	16	23	28	33	37	40	44	47	49	52	54	57	59	61	63	65	67	69	70	72	74	75	77	79	80	81	83	84	86	87	88	90	91	92	94		
						2	3	5	6	8	9	11	13	14	16	18	20	21	23	25	27	29	31	33	36	38	40	42	45	47	49	52	54	57	60	62	65	68	71	74	77	80	
102						-14	+3	13	21	26	31	36	39	43	46	49	51	54	56	58	61	63	65	66	68	70	72	73	75	77	78	80	81	83	84	86	87	88	90	91	92	93		
						1	3	4	5	7	9	10	12	13	15	17	18	20	22	24	26	28	30	32	34	36	38	40	43	45	47	50	52	55	57	60	63	65	68	71	74	77	
103						-26	-2	+10	18	24	30	34	38	42	45	48	50	53	55	58	60	62	64	66	68	70	71	73	75	76	78	79	81	82	84	85	87	88	89	91	92	93		
						1	2	3	5	6	8	9	11	12	14	16	17	19	21	23	25	26	28	30	32	34	37	39	41	43	45	48	50	53	55	58	60	63	66	68	71	74	
104							-8	+6	15	22	28	33	37	40	44	47	50	52	55	57	59	61	63	65	67	69	71	73	74	76	77	79	80	82	83	85	86	88	89	90	92	93		
							1	3	4	6	7	9	10	12	13	15	16	18	20	22	23	25	27	29	31	33	35	37	39	41	44	46	48	51	53	55	58	61	63	66	69	72
105							-18	+2	12	20	26	31	35	39	43	46	49	51	55	56	59	61	63	65	67	69	70	72	74	75	77	79	80	82	83	85	86	87	89	90	91	93		
							1	2	4	5	6	8	9	11	12	14	15	17	19	20	22	24	26	28	30	31	33	35	38	40	42	44	46	49	51	53	56	58	61	63	66	69
106							-34	-4	+9	18	24	29	34	38	42	45	48	51	53	56	58	60	62	64	66	68	70	72	73	75	77	78	80	81	83	84	86	87	88	90	91	92		
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107								-11	+5	15	22	28	33	37	41	44	47	50	53	55	57	60	62	64	66	68	70	71	73	75	76	78	79	81	83	84	85	87	88	90	91	92		
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109								-46	-6	+8	17	24	29	34	38	42	45	48	51	54	56	58	61	63	65	67	69	70	72	74	76	77	79	80	82	83	85	86	88	89	90	92		
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111									-26	-1	+11	19	26	31	36	39	43	46	49	52	55	57	59	62	64	66	68	70	71	73	75	76	78	80	81	83	84	86	87	89	90	91		
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113										-16	+3	14	22	28	33	37	41	44	48	50	53	56	58	60	63	65	67	69	70	72	74	76	77	79	81	82	84	85	87	88	89	91		
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114										-31	-2	+11	19	26	31	36	40	43	47	50	52	55	57	60	62	64	66	68	70	72	74	75	77	79	80	82	83	85	86	88	89	91		
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115											-9	+7	17	24	29	34	39	42	46	49	52	54	57	59	61	64	66	68	70	71	73	75	77	78	80	81	83	85	86	88	89	90		
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116											-18	+3	14	22	28	33	37	41	45	48	51	54	56	59	61	63	65	67	69	71	73	75	76	78	80	81	83	84	86	87	89	90		
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117											-35	-3	+11	19	26	31	36	40	44	47	50	53	55	58	60	63	65	67	69	71	72	74	76	78	79	81	82	84	85	87	88	90		
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